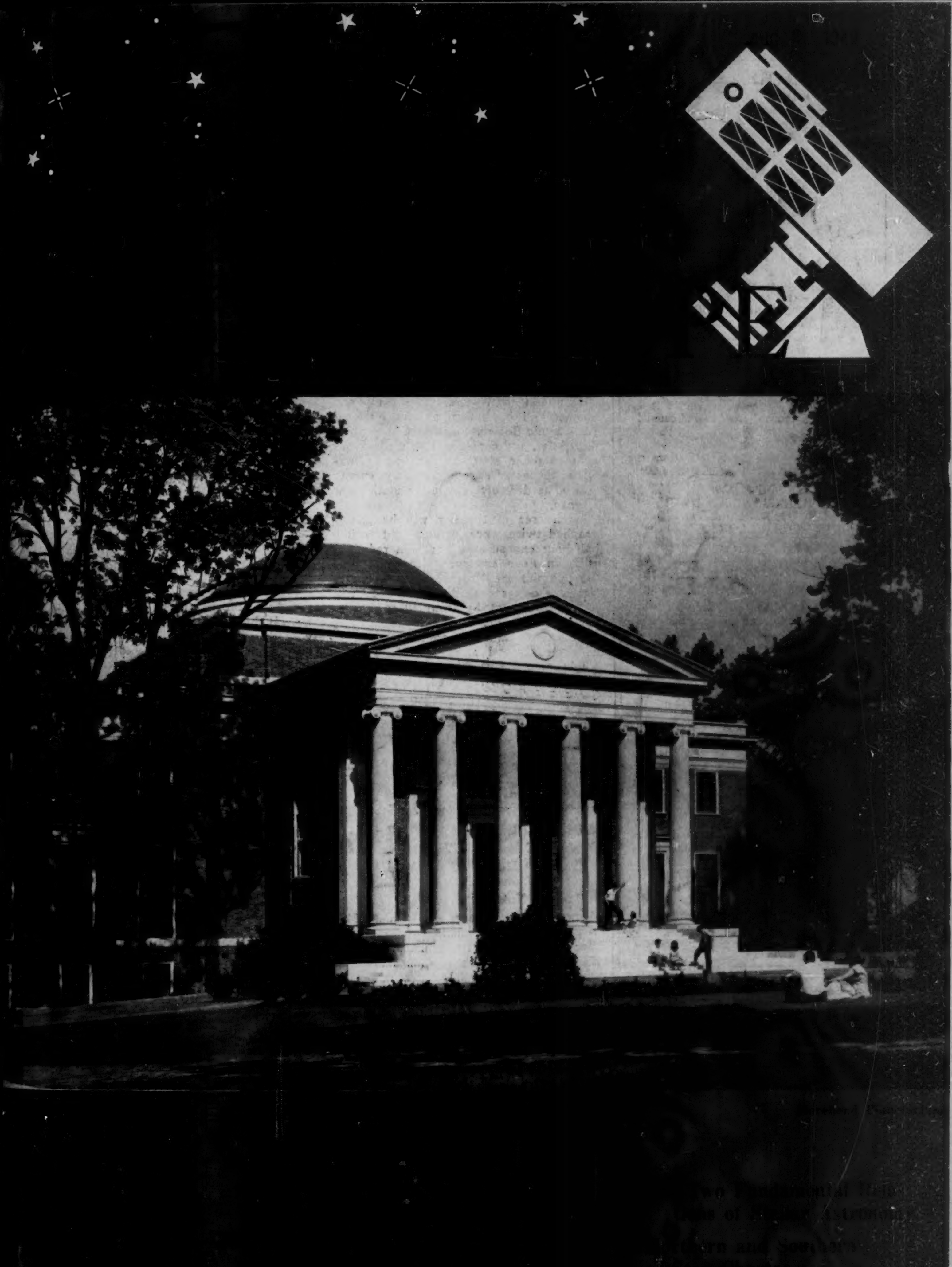

Sky and TELESCOPE

A NEW ATLAS AND THE FIRST HALE PHOTOGRAPHS

JULY 19th was the date scheduled for the start of a series of some 2,000 photographs of the heavens to be made during the coming four years by the 48-72-inch Schmidt camera on Palomar Mountain. The resulting photographic map of three fourths of the entire sky will penetrate space to an average distance of 300 million light-years. The completed project will be known as the National Geographic Society-Palomar Observatory Sky Atlas, and copies will be made available to other observatories and institutions at cost. A supplementary survey will be needed to complete the south polar regions.

Each area of the sky will be photographed twice, once in blue light with a half-hour exposure and once in red light with an hour exposure. The plates of the Schmidt are 14 by 14 inches, covering a six-degree field. Each area will overlap the next by from 10 to 20 per cent. Even under ideal conditions, it is expected to obtain no more than four pairs of matching red and blue plates in a single night. But when completed, the survey will have recorded some 500 million stars and perhaps 10 million exterior galaxies.

In its final form, the sky atlas will be the equivalent of 20 oversized volumes. The plates will be reproduced on double weight photographic paper stock, according to present plans. Each plate will carry a set of celestial co-ordinate markings, and text material will probably be limited to a description of the details of procuring the exposures. Thanks to financial aid by the National Geographic Society, it is hoped that the atlas can be turned out at a price close to two thousand dollars per copy, possibly less to insure wide distribution.

Dr. Edwin P. Hubble is scientific director of the mapping project. The actual photographic work is in charge of Dr. Albert G. Wilson, California Institute of Technology, assisted by Dr. Josef J. Johnson and Robert G. Harrington.

Meanwhile, in the June **Publications** of the Astronomical Society of the Pacific, Dr. Hubble presents the first photographs with the 200-inch Hale reflector, made as routine tests to record progress in the program of adjustments. For these pictures,

(Continued on page 257)

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WHOLE NUMBER 94

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BACK COVER: The nebu'a in Orion, M43, and part of the Great Nebula, M42, photographed with the 100-inch reflector of the Mount Wilson Observatory, January 27, 1949, by John C. Duncan, Whitin Observatory, Wellesley College. This exposure, of 15 minutes, was made in red light, using Eastman 103aE emulsion and red Plexiglas filter No. 160. With the page held erect, west is at the top, north at the left, and south at the fold. The scale of the reproduction is approximately 4.8 seconds of arc to one millimeter. (See page 255.)

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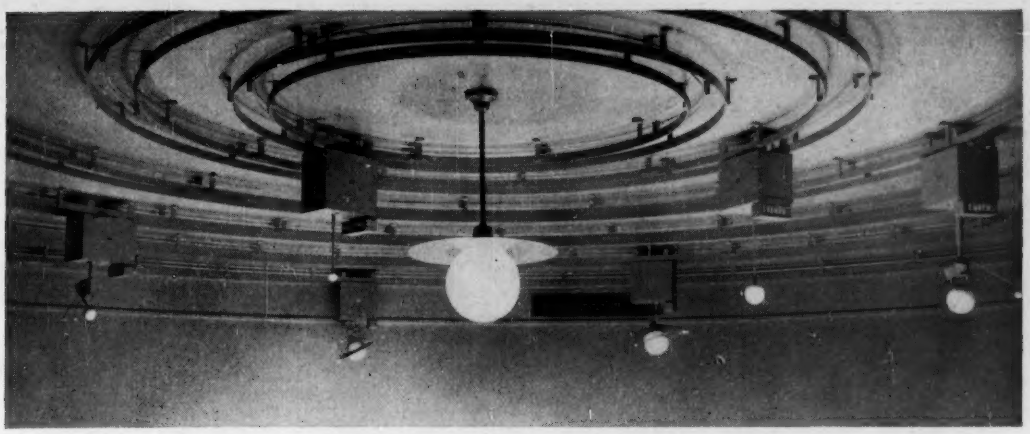


The Copernican planetarium in the Morehead Building of the University of North Carolina is similar to that in New York's Hayden Planetarium. Photographs in this article are all by Bob Brooks.

THE MOREHEAD PLANETARIUM

By Roy K. Marshall, *Director, Morehead Planetarium, University of North Carolina*

THE SIXTH installation of a Zeiss planetarium in the Western Hemisphere, and the first to be located on the campus of a university, opened its doors to the public on the evening of May 10, 1949. There had been several preview performances, before members of the North Carolina Academy of Science, the faculty of the University of North Carolina at Chapel Hill, and the large dedication audience.

At the dedication, John Motley Morehead, of New York, the donor, turned over to the university the $3,000,000 building, which was accepted by Governor Kerr Scott in the name of the university and the people of North Carolina. The principal address was given by U. S. Senator Frank Graham, former president of the university. The formal ceremonies were followed by a presentation of the inaugural demonstration, "Let There Be Light," in which dramatic episodes made possible by the perforated stainless steel dome assisted in tracing the development of man's knowledge of nature from the days of fear and superstition to the modern times of scientific research. This demonstration continued through the opening period of the Morehead Planetarium. Demonstrations are given each night at 8:30 and at 3 o'clock on Saturday and Sunday afternoons. Between May 10th and June 3rd, many special demonstrations were held for students of the public schools of Chapel Hill and other places in North Carolina.

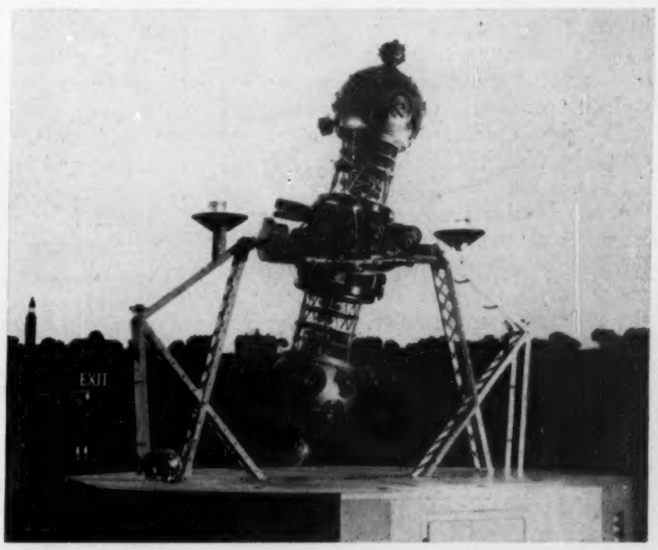
The Morehead Building contains, in addition to the planetarium, exhibit halls for the display of models and instruments, as well as transparencies and other materials to enhance the performance. The second Fecker installation of a large orrery, 35 feet in diameter, similar to the one in New York's Hayden Planetarium, is in the Morehead Building. With the destruction of the prototype in the Deutsches Museum in Munich by bombing and fire, these are the only such large mechanical planetarium installations in the world.

Above the Copernican orrery, as it is called, is a memorial rotunda, with 16 tall monoliths of Ozark marble supporting a domed ceiling and arranged around a circular room paneled in walnut. Eleven paintings, including a Rembrandt and others by well-known masters, constitute the memorial to Genevieve B. Morehead, late wife of the donor. In one of the niches formed by a pair of columns is a fine new clock by Howard, especially designed and constructed for the building. The pendulum rod, of invar steel, is a bit more than 13 feet long, so that the beat is each two seconds. The face of the clock is surrounded by a sculptured annulus carrying the symbols of the zodiac.

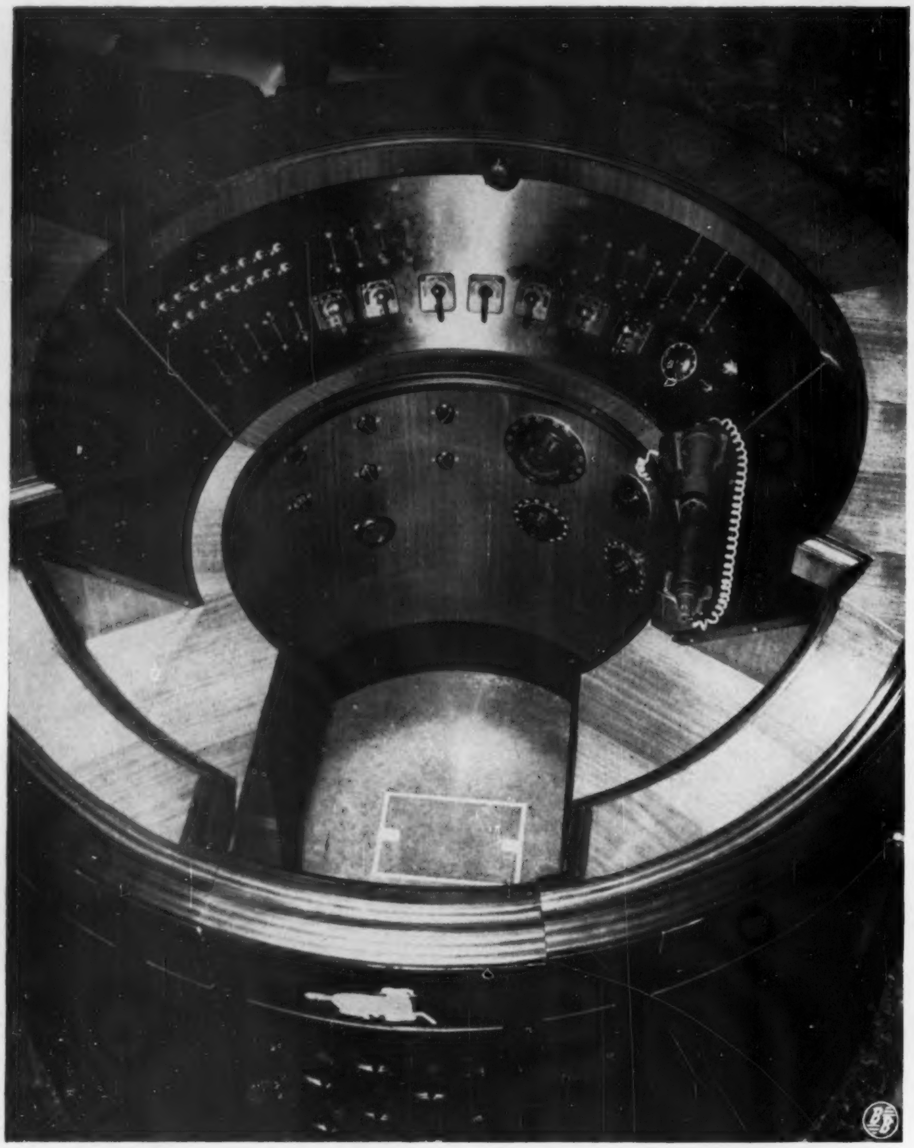
A set of 25 chimes accompanies the clock, in another niche. There is a separate peal for each day of the week. On Monday, the chimes of Silchester Church are heard; on Tuesday, the peal is Whittington; on Wednesday, the Tennyson Church; on Thursday, Derby; on Friday, Guilford; on Saturday, the Winchester peal, of unknown origin; and on Sunday, Fort Augustus. These beautiful peals of English churches never fail to bring comment from the visitors, who have been surfeited with the Westminster chimes, which are not used with the clock of the Morehead Building. The chime closet contains a keyboard on which manual operation is possible, any tune in any key being practicable because of the more than two-octave spread.

The top of the niche for the chimes contains an aneroid barometer by Henry Browne and Son, of England. It is 18 inches in diameter, and it too is circled by a band containing the signs of the zodiac. The operating elements of the barometer weigh 14 pounds.

On either side of the rotunda is a large exhibition room, to be devoted particularly to art and handiwork of a nonscientific nature. Above these rooms, in



The Zeiss projector of the Morehead Planetarium was formerly in operation at the planetarium in Stockholm, Sweden. Here it is pictured in its present location, with the University of North Carolina buildings forming a part of the skyline of the chamber.



The control console and lecturer's booth in the Morehead Planetarium.

the area of the building restricted for special purposes, are the Faculty Lounge which, as its name indicates, is for the use of the staff of the university, and the University Room, to be used for teas and similar functions.

On the third floor, a state dining room for 24 persons has been provided, with a roof terrace on either side of it. Pillars of Swedish granite blend with the deep walnut paneling, while crystal spray wall lights illuminate the four paintings of early North Carolina teachers and leaders.

The Faculty Lounge, the University Room, and the dining room provide a long-felt need for such properly fitted social rooms for occasions important to the university community. Faculty and staff groups of neighboring institutions, such as Duke University, State College in Raleigh, and Woman's College in Greensboro, have already been entertained there, as well as several other organizations.

In the scientific exhibition rooms, there have been assembled the original astronomical instruments of the University of North Carolina, purchased in England by President Joseph Caldwell in 1824 and set up in 1831 in the first building in the country erected specifically as an astronomical observatory. When President Caldwell died in 1835, interest waned, and the building burned in 1838, but the instruments had been removed two years earlier. They were then stored in various attics, with only occasional use, and have now been put into good condition and have been given an honorable home.

There is an altitude-azimuth instrument, by Simms, with circles about two feet in diameter, engraved to five minutes of arc on platinum, instead of silver. A meridian transit, also by Simms, and a refractor by Dollond, are in this old collection, as well as a Robert Molyneux clock which runs well despite its age and the tribulations through which it has passed.

Contrasted with these original instruments of the university is a new Fecker 15-inch Cassegrainian reflector, delivered since World War II. It is to be mounted and used for instruction and observation by the public as soon as time permits for the design of an observatory and the selection of a site. Unfortunately, no provision has been made for a place for the telescope in the Morehead Building.

The projection dome of the Morehead Planetarium is 68 feet in diameter, and the bottom rim carries the silhouette of familiar structures of the campus. Below this is a light trough containing 177 lamps in three color circuits, by means of which special effects can be obtained for dramatic presentations. These lights, pleasingly blended to produce a warm white, are always used as the visitors enter the room. There are also eight amber spotlights on the instrument, from a platform enclosing the lower portion of the structural support, and these wash the Zeiss projector with golden light, to enhance its appearance.

There are 493 permanent theater-type seats, cushioned in blue leatherette. Because there are so few seats in the large room, there is ample leg room for everyone, and generous aisles. The tilt of the seats is such that a minimum of neck strain is experienced by the visitors.

The lecturer's console is contained in a circular enclosure of formica-simulated wood, trimmed with genuine Macassar ebony. By careful co-operation between electrical engineers, cabinet makers, and the director, this has been made the most convenient of all planetarium consoles in America. There are all the familiar controls, and many auxiliaries already built in, although the pieces of apparatus to be controlled by them have not yet been made. There is room for 100-per-cent expansion of controls without leaving the 45-degree panel of black formica carrying the switches. For the first time, the motors are controlled by single reversing switches. The space has been so laid out that it has been unnecessary to provide either illumination for the console or labels for the various switches.

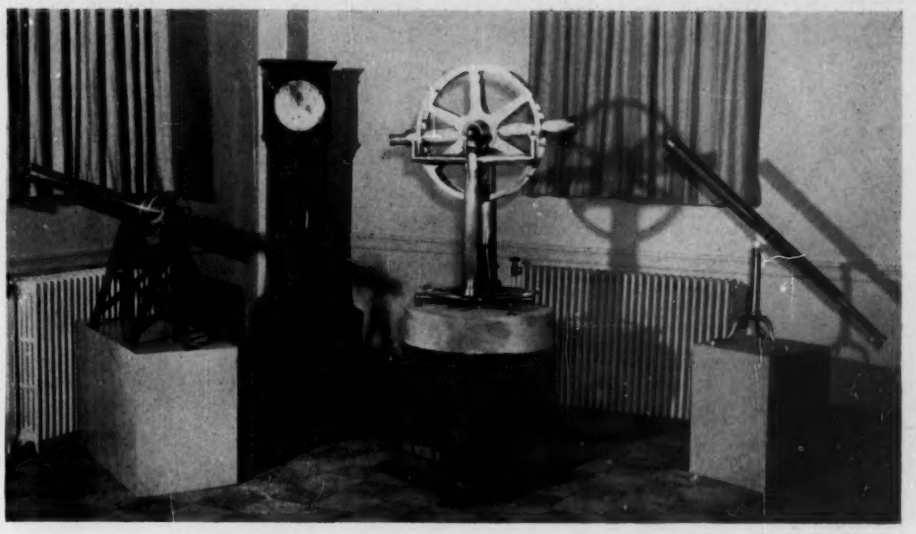
As shown in the photograph of the panel, motor switches form a bank of seven in the center at the bottom. Immediately to the left are switches for the meridian, equator-ecliptic, names, and the like, and above these are switches for constellation projectors. To the right of the constellation switches are those for stars, moon, planets, and sun, in that order from left to right. At the extreme upper right are three switches for the horizon and the white and blue room lights. Below these are comet projector, eclipse projector, variable stars and cardinal points controls. There is also a switch and a volume control for the sound system, with a pilot light to indicate when the turntable is going.

Lantern slides and music will be operated by the demonstrator himself. Dimmers for the various projectors are all below the shallow shelf that is just

underneath the switch panel. The circuit breakers, of standard American magnetic type, are approximately alongside the demonstrator, one bank on each side. The pointer, lying in its cradle on the right-hand side, has a self-coiling telephone wire that easily stretches to more than four feet long. All operations are confined to an angle of 90 degrees in front of the demonstrator, and he has no more than 15 inches to reach for any control.

From May 10th, the date of the first public demonstration, through Monday, July 4th, the total attendance was 30,000, including the invited guests at the previews. The total paid attendance through the same period was nearly 26,000. The lack of a large metropolitan population is apparently made up by the willingness of the citizens of North Carolina to support something new and something that is as fine as any similar institution in the North. The Morehead Planetarium will be operated as a public institution, as are the other planetariums in America, and it will be integrated into the curriculum of the university as well, when the next full academic year opens. The director of the planetarium is also professor of astronomy in the university, and will head the newly created department of astronomy. The planned school program for the children of the state will go into effect in October. Judging from the experience of this spring, it will be exceedingly popular.

This beautiful new building is an ornament not only to the fine campus of the oldest state university in America, but to the southeastern United States. The experiment of operating a Zeiss planetarium in a small town, and on a university campus, is one which should be of interest to everyone concerned with astronomy and with museum practice.



The Caldwell astronomy apparatus, purchased in England in 1824 and now on permanent exhibit at the Morehead Planetarium. The Simms transit is at the left, the Simms altitude-azimuth instrument circle is in the center, the Dollond refractor at the right. The Molyneux clock is against the wall.

TERMINOLOGY TALKS—J. Hugh Pruett

Leader and Follower

Sunspots tend to appear in groups. Quite commonly a large penumbra holds several umbrae. Single spots may break out with no nearby companions, but the more frequent event is for two spots to develop three or four degrees apart and in a line almost east and west of each other. The one in the direction of the sun's rotation is called the *leader*; the other, the *follower*. From day to day these spots change in size and shape and number, and may finally spread 10 degrees or so apart. Numerous small spots may form between them until the entire group becomes very large and populous. The largest group ever photographed appeared early in 1947, and by April 7th had an area of 4,897 millionths of a solar hemisphere. The largest previously photographed developed early in 1946.

The intermediate and follower spots usually break up and disappear first, thus leaving only the more symmetrically formed leader spot. As the solar rotation period is several days less than a month, this spot may be carried behind the sun for a disappearance of about two weeks. While gone it may completely disintegrate, or it may again come into view as it turns up on the opposite side of the sun from its disappearance. An individual spot occasionally lasts for several rotations. The longest duration on record was 18 months for the famous spot of 1840-41.

Sunspot Cycles

The regular observer of the sun is quite aware that he cannot find this luminous globe speckled with spots any time he turns his telescope in that direction. Sometimes the solar surface is so clean that one has doubts that a good focus has been obtained. Galileo's critics would have exulted in such occasions as proving their contention that "the sun is a pure body." Even in such extended periods of calm, however, quite "sizable" spots may at times be found. And a few years later old Sol's shining face will be almost constantly disfigured.

In 1825, Heinrich Schwabe, of Dessau, Germany, began regular observations and recordings of the positions and sizes of sunspots. After 20 years he was thoroughly convinced that about every decade spots were much more numerous than at other times. His work was continued by Rudolph Wolf, of Zurich, Switzerland, and to the present by others. From records back to the time of Galileo, it is easily shown that on an average the spots are most numerous about every 11 years. A time of greatest spottedness is known as a *maximum*; of least, a *minimum*.

Although the times between two maxima average 11.2 years, these periods are quite irregular, and have been known to be as short as seven years or as long as 17. The last four maxima seem to have occurred in 1917, 1928, 1937, and 1947. Had we only these to use in our averaging, we should agree with Schwabe's first report that the period was 10 years.

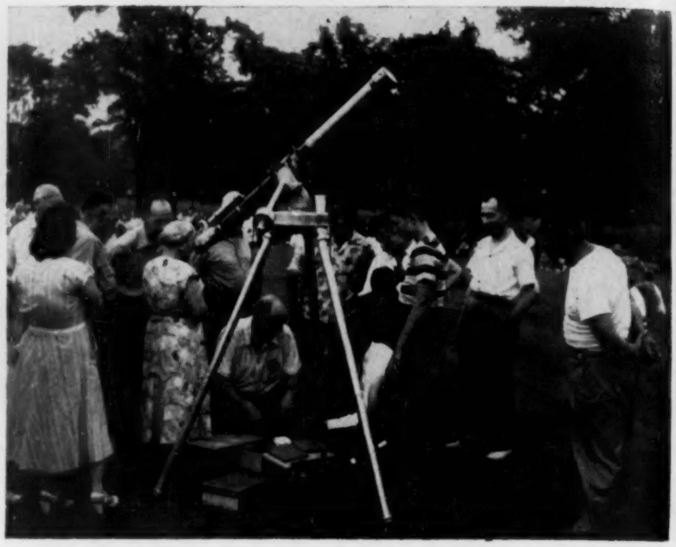
Sunspot Numbers

In order to compare the solar spottedness at various times, Wolf devised a system which has been generally followed by students of this phenomenon. We may read that on a certain day the Wolf sunspot number was 128, and a week later 86. One would correctly assume that spottedness was more intense in the first case — but just what do the figures indicate?

The formula for the sunspot number is generally given as $N = k(10g + f)$. In this, g represents the groups of spots which are observed, and f the total number of individual spots of all sizes that may be found, both those standing alone and included in groups. Disregarding k, should an observer today find the entire solar disfigurement consisted of two groups, one of 11 spots and the other of 13, and 15 isolated spots at various places, the substitution in the formula becomes:

$N=(10\times 2)+(11+13+15)=59.$

Since there is a great variation in the sizes of telescopes and in the seeing conditions at different observing stations, to each observer or observatory there is assigned a value of k that will give N as nearly as possible a value that will be the same everywhere at any certain time, and will be in agreement with a value of unity when used under conditions employed by Wolf.



Scenes at the July 2nd star party in Wade Park, Cleveland. Left: David Dietz, science editor, Cleveland "Press," discusses popular astronomy over the loudspeaker system. Right: Observers at the telescope of Frank A. Myers (squatting beneath tripod), one of the instruments that won an award in the exhibit at the Astronomical League convention.

CLEVELAND CONVENTION

A STIMULATING PROGRAM of practical advice to amateur astronomers and a heat wave of record-breaking proportions highlighted the Astronomical League convention in Cleveland on July 4th weekend. About 120 amateurs were registered from over the country, including the league treasurer, Carl P. Richards, and Mrs. Richards, of Salem, Ore., representing the Northwest region societies. Members-at-large Dr. Jesse Moore, St. Joseph, Mo., and Robert G. Harder, Omaha, Nebr., were also on hand. E. M. Brewer, of Dallas, Tex., was present in order to carry news of league activities to his newly formed home society.

For amateurs wishing a practical demonstration of how to present astronomy to large numbers of people, the star party in Wade Park on Saturday evening was highly significant. The event was sponsored by the Cleveland *Press* and the Cleveland Astronomical Society, with the Astronomical League also participating this year. Several thousand people gathered to observe the moon, Saturn, double stars, and Jupiter with more than a dozen instruments set up over a large area. The telescopes were provided and operated by various members of the Cleveland society and by league convention delegates.

A loudspeaker system was used by David Dietz, of the *Press*, Dr. J. J. Nassau, president of the Cleveland Astronomical Society and director of Warner and Swasey Observatory, both veterans of 20 years experience with star parties, and by visiting amateurs. When the evening had grown dark enough, sound motion pictures were projected on a large screen set some distance from the cluster of telescopes, and there was ample opportunity for the public to acquire an introduction to astronomy.

Toward the close of the convention, during the informal panel on instrumentation under the chairmanship of Leo N. Schoenig, of the AAA of Pittsburgh, there was a general discussion of the use of television in astronomy. Television broadcasts of such events as eclipses of the moon are already bringing to the public an awareness of astronomical phenomena, and now there appears good prospect for the individual radio-minded amateur to construct his own television type of apparatus to permit simultaneous observation of bright celestial objects by a group of persons. William A. Rhodes, of Phoenix, Ariz., has successfully designed apparatus that reproduces on a screen telescopic images of the moon and planets, and which can detect 1st- and 2nd-magnitude stars (*Radio-Electronics,* June, 1949, page 24). Walter Wilkins, 6124 Dewey Ave., Indianapolis, Ind., editor of the Indiana Astronomical Society *Bulletin,* has found that for a materials cost of about 300 dollars a telescope can be rigged up to receive images fainter than the naked eye can detect, transmit them to a warm room, and project them to a screen the size of a home movie screen. Coaxial cable permits the projection to take place as much as 1,000 feet from the telescope.

Three section meetings, devoted respectively to solar observing, lunar and planetary work, and double and variable stars, were replete with reports on observing techniques and programs, and keynoted the convention and the league's aims for getting activity sections well under way. Rolland R. LaPelle, of Springfield, Mass., was in charge of the section meeting programs. He described the operation and construction of an interference polarizing monochromator, a filter designed many years ago by Lyot and Evans to permit direct observations of the sun in monochromatic light. Professional astronomers are handicapped by the present high cost of commercial manufacture of such devices, and Mr. LaPelle transmitted a request from solar astronomers for amateur instrument makers with sufficient degrees of skill to experiment with producing these filters at lower cost. The chief requirement is for the manufacture of very thin sheets of quartz, optically plane-parallel and to rigid thickness tolerances.

The AAVSO solar division was described by Ralph N. Buckstaff, of Oshkosh, Wis., chairman of the North Central region. He uses a 3-inch telescope to get his daily sunspot counts, and projects the solar image through a 5-inch telescope on cards bearing Stonyhurst disks for making detailed drawings of spot areas. He stressed the value of observations of variations in the granulation of the photosphere.

The probable position of the axis of Venus as inferred from visual observations was reported in a paper by Thomas Cragg, Los Angeles, Calif. He proposes that at the present time the axis of Venus is very nearly perpendicular (within five degrees) to the plane of the planet's revolution around the sun. Belts seen in the Venusian cloud surface are very nearly at right angles to the lines joining the cusps. There are also cusp-cap protrusions, which Walter Haas, director of the Association of Lunar and Planetary Observers, suggests may be similar to polar caps on other planets or which may be caused by masses

of cold air originating at or near the poles of the planet. Mr. Cragg's paper described the evidence for a period of rotation of Venus, as yet undetermined, that should be neither very short nor very long.

Ray Missert, of Buffalo, N. Y., discussed a paper by Mr. Haas describing observations made on April 12, 1949, of the apparent occultation of a star by a satellite of Jupiter. For seven minutes the star was invisible, but as it was of the 9th magnitude the possibility exists that it may have merely become lost in the glare of the 6th-magnitude Jupiter II. Relative motions of satellite and star indicated that an occultation had actually taken place.

Mr. LaPelle, in his capacity as chairman of activity sections of the Astronomical League, read a letter from Dr. Clyde Tombaugh, discoverer of Pluto while on the staff of the Lowell Observatory and now living at Las Cruces, N. M. Amateur observations of the planets by instruments of six inches aperture and upward are encouraged. Dr. Tombaugh suggests that modest telescopes equatorially mounted but without driving mechanisms can be used by setting them ahead in right ascension and allowing the object to drift across the field of view. In long-focus instruments, where coma near the edge is scarcely perceptible, this is especially satisfactory and is the method employed by the veteran planetary observer with a 12-inch Newtonian of 150 inches focal length that he made himself. At present he is processing two 16-inch mirrors which he hopes to finish and mount in the near future.

A few years ago Dr. Tombaugh discovered that an amber filter of moderate density worked wonders with the full moon, improved the seeing by a point or two, and greatly reduced the glare. With this filter, a wealth of rather curious detail of small light and darkish areas appears under high solar illumination.

The activity sections chairman discussed planetary photographs by Lowell Observatory; the lantern slides shown included drawings of Mars for comparison with the Lowell photographs of that planet.

In discussing instrumental requirements for planetary observing, Mr. LaPelle stressed the need for long focal ratios and high power, plus practice and patience in training one's eye. Ramsden eyepieces are not satisfactory; Kellner and orthoscopic types are needed, preferably antireflection coated. On most reflectors, a Barlow lens is necessary to procure the required magnification.

As for double star observations by amateurs, a letter from Dr. G. Van Biesbroeck, of Yerkes Observatory, stated that there is a very definite need for this. The work is simple, can be done any time, requires practically no computation, and yields interesting results to the observer. Reflectors can be used, but Cassegrainians are preferred to procure long focal length. Equatorial clock-driven mountings are essential. A filar micrometer with illuminated wires is required to make double star position angle and separation measures. This device is of delicate construction but requires hardly any upkeep. Dr. Van Biesbroeck advises that the mechanic of the Yerkes Observatory in his spare time will make simple but adequate micrometers for amateurs for 250 dollars each.

Double star measures are of fundamental value to astronomy in that they give us information about stellar masses directly. Too few observers are available to keep track of the many pairs that are in orbital motion. Many a pair, after changing slowly for decades, speeds up toward a critical phase of very rapid motion which will define the orbit completely. If such phases go by unobserved, our knowledge about the true character of the motion can be delayed for scores of years. There is constant need for alert workers who will record the orbital motions for use by present and future astronomers. The program of stars in need of measurement has to be adjusted to the size of the instrument and modified as time goes on. Dr. Van Biesbroeck will gladly contribute such lists of stars to amateurs who have the instrumentation and the energy to maintain a program of serious observation of double stars.

In a discussion unusual for its detailed accounting of the actual steps and problems involved in observing, Edward A. Halbach, of the Milwaukee Astronomical Society, and past president of the league, described the variable star work of the AAVSO. He outlined the methods of using variable star charts and estimating magnitudes.

Other talks were presented by John Ferro, of the George Gregory Memorial Observatory, on the origin of lunar formations; Fred H. Cox, Norfolk, Va., on the origin of the solar system; by Owen Gingerich, Goshen, Ind., on the observation of objects in Messier's catalogue; by Paul W. Stevens, Rochester, N. Y., on the Metonic cycle and eclipses near bright stars; and by John Andrew, Duluth, Minn., concerning auroral work for amateurs.

At the afternoon session on Saturday, the traditional roll call of member organizations and accompanying society reports served to acquaint the delegates with one another and provided numerous valuable suggestions for local activities. Mentioned a number of times was the film, The Story of Palomar, which has been shown by many local groups at clubs, schools, and public gatherings. At Louisville, 900 people attended a showing of this film and that on solar prominences by the University of Michigan;

Members and guests at the Cleveland convention of the Astronomical League, Case Institute of Technology, July 2-4, 1949.

A table at the Cleveland convention banquet. The first five persons on each side are: (left) Mrs. Carl P. Richards and Mr. Richards, Salem, Ore.; Mr. and Mrs. E. A. Halbach, Milwaukee; Mrs. Ralph N. Buckstaff, Oshkosh, Wis.; (right) Miss Laura L. Mayer, Cleveland; Miss Cora E. Zemlock, Milwaukee; Mrs. Roy L. Dodd and Mr. Dodd, Milwaukee; and Mrs. Nancy R. Bolton, Cambridge, Mass.

the Louisville Astronomical Society maintains one of 30 stations co-operating with the American Ornithological Union to observe bird flights across the sun.

Although the National Capital Astronomers in Washington, D. C., has 129 members plus 35 juniors, its average attendance at meetings is 175 persons. The Beaver County Astronomical Society at Beaver, Pa., solved its programing problem by electing three program chairmen instead of one, each chairman taking care of planning three of the 10 meetings during the year; the last is an observing meeting. The George Gregory Memorial Observatory of the Paul Revere Boys Club, Jersey City, N. J., has an observing department in which boy astronomers observe sunspots, weather, and carry on nova search. There is also an astrophotography department and an optical shop in which eight mirrors are being worked at present.

The Milwaukee Astronomical Society is running eight open houses for the public this season at its observatory, where two more telescopes, a 10-inch and a 12-inch, are to be housed in addition to the present 13-inch reflector and auxiliary instruments. Soon six members of the MAS expect to operate a pair of auroral cameras at the ends of a 30-mile baseline.

The roll call revealed the following membership of the league:

Region	*Societies*	*Members*	*Juniors*
Northeast	13	870	400
Middle East	19	906	55
North Central	7	290	—
Northwest	3	77	—
Unorganized	5	511	—
	47	2,654	455

Three organizations included above were accepted as new members by the national council at this convention: the Cleveland Astronomical Society, the Pontiac Astronomical Society, and the junior group of the National Capital Astronomers.

Newly elected officers to serve from September, 1949, for one year are: *president,* Charles H. LeRoy, Pittsburgh (at present chairman of the Middle East region); *vice-president,* Carl P. Richards, Salem, Ore. (who has served for several years as treasurer); *secretary,* James B. Rothschild, New York City (past executive secretary); *treasurer,* William C. Oberem, Buffalo, N. Y. (retiring vice-president). Following the resignation of Mr. Rothschild as executive secretary, Grace C. Scholz, Washington, D. C., presently chairman of the junior activities committee, was appointed to his position.

Charles H. LeRoy, of the Amateur Astronomers Association of Pittsburgh, president-elect of the Astronomical League.

Amendments to the league by-laws were proposed, on which member organizations will vote by mail. One concerns the adding of each regional chairman to the national council; one defines and regulates more closely the league status of junior member organizations; one provides for changing the office of executive secretary from an appointive to an elective office, with a three-year term. The council, among other actions, raised the regional share of dues from the minimum 20 per cent provided for in the by-laws to 40 per cent, effective with dues paid for the fiscal year commencing May 1, 1949.

At the convention banquet held Saturday evening preceding the star party, with Royce Parkin, convention chairman, as toastmaster, Dr. S. W. McCuskey, head of the mathematics department at Case Institute of Technology and on the staff of Warner and Swasey Observatory, gave an illustrated talk on the expansion of our concepts of the size of the Milky Way galaxy. From a system estimated by Herschel from his star gauges to be about 7,000 light-years across and 1,400 light-years thick, through von Seeliger's 12,000 by 3,000 light-years, to Shapley's original 250,000 by 30,000, the Milky Way has finally been determined to be about 100,000 light-years in diameter and 10,000 light-years thick. One hundred years after Herschel, von Seeliger established the working principles that the stars are not uniformly distributed in space, are not all the same intrinsic brightness, and are subject to the effects of interstellar absorption of their light. Early in the 20th century the work of Kapteyn and van Rhijn "expanded" the galaxy to 60,000 light-years across. Later Shapley demonstrated the coincidence of the center of the system of globular clusters with that of the Milky Way system of stars, and in 1930 Trumpler made the first quantitative absorption measures of starlight out to distances of 3,000 light-years.

The first approximation in our picture of the galaxy is now well established and we are starting to investigate the details in the structure. Such fast cameras as the Warner and Swasey Schmidt permit observations of stellar magnitudes, colors, and spectral types of greater accuracy than ever before. Infrared plates show that there are many more red stars in space than previously thought to exist. Dr. McCuskey commented that not enough astronomers are engaged in the study of the Milky Way.

Convention delegates had an opportunity to inspect Milky Way research equipment firsthand at the Warner and Swasey Observatory open house Sunday evening. At intervals between visual observing with the 24-36-inch Schmidt telescope and the 9½-inch refractor, Dr.

Nassau described the observatory's work and demonstrated the new ceiling mural in the lecture hall, which depicts the orbits of the planets and satellites and Halley's comet, in fluorescent light when the room is darkened.

Three miles west of the Case Institute, where the meeting was held, is the Cleveland Museum of Natural History, sponsor of the activities of the Junior Astronomy Club. The club workshops were open for inspection Sunday night also. One room contains 16 spindles on which to grind and polish mirrors; adjoining it is an assembly room and workshop; the basement is being made into a machine shop. Since its start this spring (see *Sky and Telescope*, May, 1949, page 172), 173 8-power telescopes have been assembled from war-surplus lenses and other inexpensive or donated materials, all the work being done by the juniors themselves.

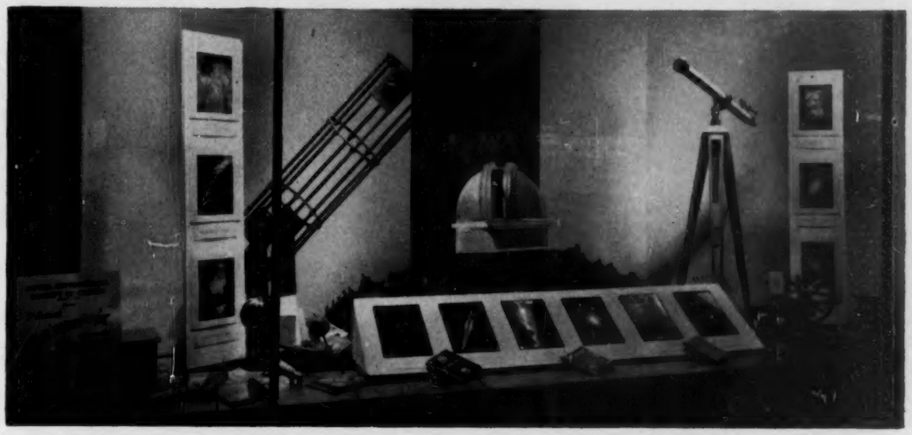
Between sessions, delegates inspected the exhibit of amateur-made instruments, devices, and photographs. The judges were Dr. Paul Annear, of Baldwin-Wallace College, Mr. LaPelle, and Mr. Schoenig. Prizes were won by John Gregory, of Cleveland, for his Schmidt camera of five inches aperture, with guide telescope, motor drive, slow motions for guiding; Dr. J. C. Bartlett, Baltimore, Md., for his paintings of colors on Saturn and the moon; Frank A. Myers, of Cleveland, for his well-mounted portable; and by Norman Ulan, Warren, Ohio, for his mounting with clock drive of a 4½-inch objective by J. W. Draper.

Other exhibits included a 4½-inch refractor with phonograph-motor drive by Charles R. Prather, of Warren, Ohio; 6-inch RFT reflectors by Donaldson Craig, Wilbert Meagher, and Margaret Back, of the Detroit Astronomical Society; a 6-inch reflector by Cyril E. Bailey, of Detroit; drawings of Jupiter and the lunar crater Conon by E. J. Reese, Uniontown, Pa., a 6-inch reflector with motor drive by D. F. Mathe, Pittsburgh; a wooden mounting, photoelectric photometer, stop clock for occultations, an equatorial camera mounting, a spectroscope mounting, and a soldering iron for grooving pitch laps, all by G. R. Wright, Washington, D. C.

At the concluding session, the convention accepted an invitation to meet next year in the Northeast region, with the Amateur Telescope Makers of Boston, the American Association of Variable Star Observers, and the Bond Astronomical Club, all of Cambridge, Mass., as host societies. From July 1st to 3rd, 1950, the Astronomical League will convene on the Wellesley College campus, and Dr. John C. Duncan, director of Whitin Observatory at Wellesley, and Dr. Harlow Shapley, director of Harvard College Observatory, have also joined in the invitation.

H. S. F. and C. A. F.

Amateur Astronomers



The window display at Simpson's department store, set up by the Montreal Centre of the Royal Astronomical Society of Canada to advertise its fifth annual star night.

RASC OF MONTREAL HOLDS FIFTH STAR NIGHT

More than 2,500 persons attended a star party in Westmount Park, Montreal, on June 1st, where 25 telescopes owned and operated by members of the Montreal Centre of the Royal Astronomical Society of Canada were set up. Motion pictures of the moon and the Milky Way were shown, as well as lantern slides. There was a good assortment of questions presented by the public during several question-and-answer periods.

This was the Montreal Centre's fifth annual star night. Part of the publicity program included a display in the window of Simpson's department store, as shown by the accompanying photograph.

LEAGUE CONVENTION NOTES

Attendance: Eighteen states and the District of Columbia were represented as follows: District of Columbia, 5; Illinois, 7; Indiana, 4; Kentucky, 2; Maryland, 2; Massachusetts, 6; Michigan, 14; Minnesota, 1; Missouri, 1; Nebraska, 1; New Jersey, 3; New York, 14; Ohio, 31; Oregon, 2; Pennsylvania, 11; Texas, 1; Virginia, 8; West Virginia, 1; Wisconsin, 8.

Delegates registered from 25 member organizations of the league and three other amateur astronomical groups. The Cleveland society had 18 registrants; Mahoning Valley, 11; the AAA of Pittsburgh and the Buffalo ATM & O's, 9 each; the National Capital Astronomers, 8; the Detroit AS, 7; and the Milwaukee group, 6.

Dinner photographs: These, except the head table, are suitable for prints. Send Sky and Telescope 35 cents in stamps for one print, 4 by 5 inches; 50 cents for two prints. If your individual picture is not satisfactory, we shall return your stamps. Place your order by September 1st and allow a month for delivery.

Regional officers: At its business meeting on July 4th, the Middle East region elected G. R. Wright, Washington, D. C., regional chairman; Edwin F. Bailey, Philadelphia, Pa., vice-chairman; Elizabeth Fazekas, Norfolk, Va., secretary; and C. S. Johnson, Detroit, Mich., treasurer.

LOS ANGELES ASTRONOMICAL SOCIETY

Two articles in the June issue of **The Griffith Observer** describe the history and plans of the Los Angeles Astronomical Society in considerable detail. The organization was first founded in 1926 under the name Amateur Telescope Makers Society, and after having had several locations for its headquarters through the years it has finally become established at the Griffith Observatory in Griffith Park. The monthly lecture meetings are held in the auditorium of the planetarium itself. The members also may use the 12-inch Zeiss refractor on the observatory's roof each meeting night, and there are large quarters for a workshop and optical testing laboratory.

Future plans of the LAAS include a headquarters building in the Los Angeles metropolitan area, as well as an observatory to be located outside the city. Optics for a 15-inch Schmidt camera are practically finished and the mounting is partly built.

THIS MONTH'S MEETINGS

Geneva, Ill.: Observations of the Perseid meteor shower have been scheduled by the Fox Valley Astronomical Society for August 11th and 12th.

Indianapolis, Ind.: On August 7th at the meeting of the Indiana Astronomical Society, 2:15 p.m. in Cropsey Hall, Victor Maier will speak on "Variable Stars."

Kalamazoo, Mich.: The Kalamazoo Amateur Astronomical Association will hold its August 13th meeting at 8:00 p.m. at the home of Mr. and Mrs. Spencer Van Valkenburg, 125 W. Washington St., Vicksburg. Burke Hazelrigg will speak on "Finding Our Way Around the Sun."

Los Angeles, Calif.: The western convention of amateur astronomers sponsored by the Los Angeles Astronomical Society will be held on August 22-24 at the University of Southern California.

"Atomic Fission" is the subject of a talk by Leo A. Ohlinger, Northrup Aircraft Company, at the August 8th meeting of the Los Angeles Astronomical Society, to be held at the Griffith Observatory at 7:45 p.m.

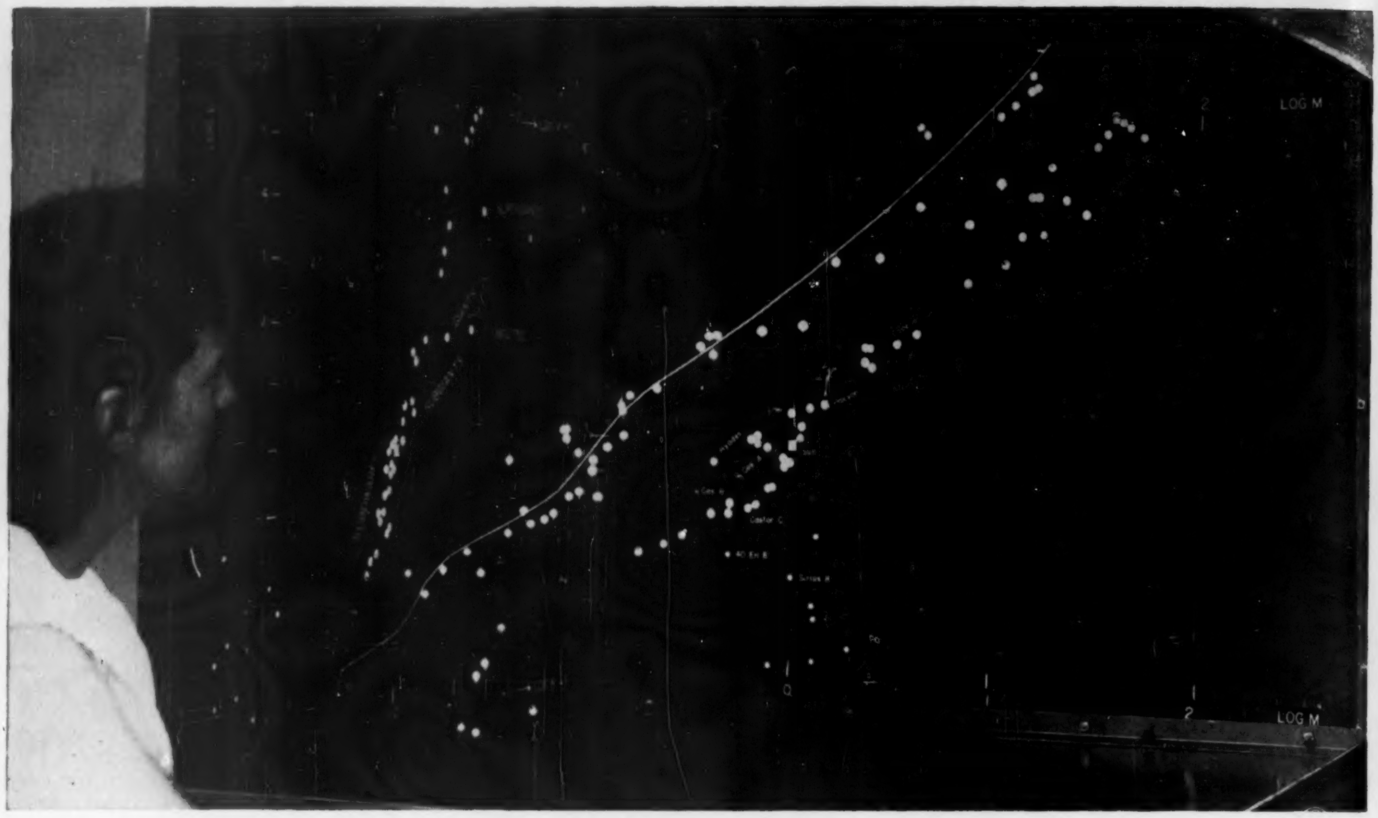


Fig. 1. Photograph of a model constructed by G. P. Kuiper to illustrate the two principal relations of stellar astronomy, the Hertzsprung-Russell diagram on the left, and the mass-luminosity relation on the right. The stars are shown by means of beads suspended on thin wires. A white string runs approximately through the main sequence. The white dwarfs form a separate group. The principal co-ordinates are the luminosity, plotted vertically, the mass, plotted to the right, and the radius, plotted at the left. Yerkes Observatory photograph.

The Two Fundamental Relations of Stellar Astronomy

BY OTTO STRUVE, *Yerkes and McDonald Observatories*

WHEN WE EXAMINE the apparent brightnesses of the stars in a cluster like the Pleiades we immediately recognize that the ***intrinsic luminosities*** of the individual members are not the same. As a rule, the brightest stars in each cluster are either blue stars or very red. The faintest members of each cluster are always red. The spread in true luminosity between the brightest and the faintest objects may be as much as 100 million. This enormous disparity makes it immediately apparent that the luminosity of a star must be a particularly important quantity and one that is likely to give us considerable information concerning the physical properties of the stars.

Unfortunately, for the stars in general, it is possible only in very few cases to determine directly the true luminosities. In a cluster we can arbitrarily assume as our unit of measurement the luminosity of the brightest star and refer to it the luminosities of all other stars, and the same can be done in the case of a double star. In order to determine stellar luminosities not relative to some unknown standard, but with respect to a known quantity, for example the luminosity of the sun, we must make allowance for the differences in the distances of the stars. The latter are now known for a few thousand objects so that for them, at least, we can compute the intrinsic luminosities in terms of that of the sun. It turns out that the most luminous stars are approximately one million times more luminous than the sun and the faintest stars are about one million times less luminous than the sun. The total range is 10^{12}.

The next significant parameter describing the properties of a star is its *mass*. This can also be determined only with difficulty. The methods now in use depend upon the universal law of gravitation as applied to double stars, either of the visual type or of the spectroscopic type. Kepler's third law provides a relation between the period of a double star and the major axis of its orbit, and Newton's law of gravitation amplifies the relation in such a way as to bring in the mass of the object. In the case of a spectroscopic binary we can measure the orbital velocity and the period. From these two quantities we obtain the size of the orbit, in linear measure, and the masses of the stars in terms of the mass of the sun. In practice, the problem is often more difficult. We must know the inclination of the plane of the orbit to the line of vision and we must also measure the spectral lines of both stars of the binary in order to compute the individual masses of the two stars. But often it is possible to resolve these difficulties and to obtain trustworthy values for the masses of the two stars. These range from about 50 times the mass of the sun to about 1/10 the mass of the sun. It is possible that even less massive stars exist as planet-like companions to such well-known objects as 61 Cygni and two or three other systems. But these small stellar masses exert only a minute effect upon the motions of the heavier members of their systems, and the actual quantities involved are almost at the limit of measurement. Nevertheless, there is no reason to think that small masses of the order of 1/100 that of the sun may not be frequent in our galaxy.

The third principal parameter in stellar astronomy is the ***radius*** of a star. In a few exceptional cases this quantity

can be measured in angular units with the help of a large interferometer. But even the largest stars are not big enough to give us an accurate determination of their radii. For example, Antares has an apparent radius of only 0.02 second of arc. Since its distance is of the order of 300 light-years, we find, according to F. G. Pease, that the true radius is approximately 150 times that of the sun. Much more reliable values of the radii can be obtained from the combination of photometric and spectroscopic observations of eclipsing variables. In principle, it is always possible from the duration of the partial and total phases of each eclipse, and from the period of the variable, to determine the radii of the two stars in terms of the distance between their centers. The spectroscopic observations permit us to express this latter quantity in kilometers; we can then also determine the sizes of the two stars in kilometers. Finally, there is a simple relation between the temperature and the radius of the star on the one hand, and its luminosity on the other. Stefan's law of radiation gives the total amount of energy emitted by a square centimeter of the surface of an object as a known numerical constant times the fourth power of the temperature. Hence, if we know the temperature from the spectrum of a star, we find immediately how much radiation is emitted by every square centimeter of its surface. But the total surface is $4\pi R^2$. If we multiply this by the radiation of each square centimeter we obtain the total luminosity. Therefore, if the total luminosity of the star, as known from its distance and brightness measurements, is divided by the radiation per square centimeter, the area of the total surface and the radius of the star are obtained.

As information concerning the radii, masses, and luminosities of the stars began to accumulate, astronomers noticed that not all combinations of the three parameters were actually realized in our galaxy. It is often convenient to represent each star as a point in a three-dimensional model in which the three co-ordinates are respectively the luminosity, the radius, and the mass. Such a model was constructed several years ago at the Yerkes Observatory by G. P. Kuiper (see Fig. 1). In a square-cornered box the vertical dimension is taken to be the logarithm of the luminosity in terms of that of the sun. Thus, when we read $\log L = +1$, the corresponding star has a true luminosity of 10 times that of the sun. The mass is represented as the horizontal co-ordinate running toward the right and is also given in logarithmic measure, log M. Zero means a star having the mass of the sun. Two would be a star having a mass 100 times that of the sun. The radius is plotted as log R along the other horizontal scale running from left to right; -2 indicates a star whose radius is 100 times less than that of the sun, and $+3$ is a star whose radius is 1,000 times that of the sun. The stars are shown by means of beads suspended on thin wires in such a way that each bead has the correct values of log L, log M, and log R. The beads are arranged in space as a fairly narrow band from the lower left side of the model to its upper right side. A white piece of string was used to show the region where the beads are most concentrated. This grouping is known as the main sequence. In addition to it there is a group of beads corresponding to very small values of L, M, and R. These stars are not a part of the main sequence, but form a separate group known as the white dwarfs. Finally, there are a number of smaller groups: the giants, the supergiants, the subgiants, and the subdwarfs, which are not very frequent in galactic space and are therefore represented by only a few objects in the model.

It is very instructive to examine the actual model from different sides. If we look at it from the right we see the beads projected against the narrow left-hand surface of the model whose co-ordinates are log L and log R. The actual projections of the beads are shown by white dots pasted on the black surface. We see that in this projection the main sequence forms a fairly conspicuous straight line with a few stars departing from it on the right and a group, distinctly removed, in the left-hand corner. The stars on the right side of the main sequence have larger radii and are different kinds of giants. The stars on the left are white dwarfs and subdwarfs.

If we examine the model from the left, as is done by the young lady in the picture, we observe the stars projected upon the right-hand side of the model whose co-ordinates are log L and log M. Here again the great majority project themselves as a narrow band running from the lower left to the upper right. This sequence is known as the *mass-luminosity relation*. It was first extensively treated by A. S. Eddington, although there have been earlier indications of it in the work of E. Hertzsprung and of others. In this projection the white dwarfs again form a detached group. They do not agree with the mass-luminosity curve, but fall below it. In other words, they have insufficient luminosities for their masses.

The left-side projection, which includes the main sequence, is almost identical with a famous diagram now known as the Hertzsprung-Russell or (H-R) diagram (Fig. 2). It was first de-

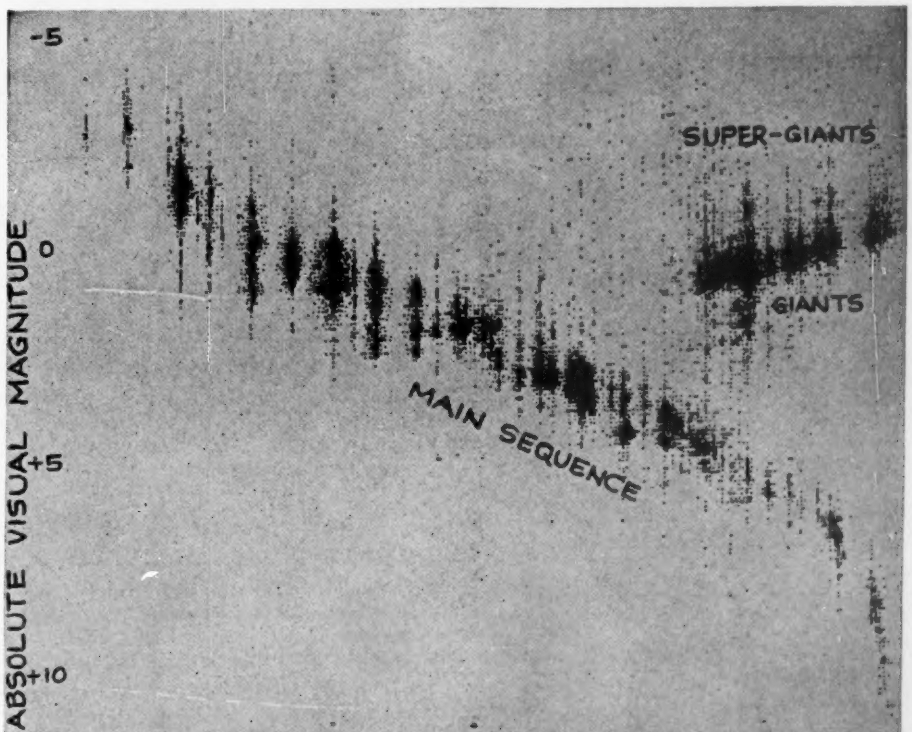


Fig. 2. The Hertzsprung-Russell diagram, from statistical studies by van Rhijn. The sun's absolute magnitude is about +5, its spectral class G. Diagram by W. Gyllenberg, Lund Observatory.

scribed by Henry Norris Russell in a famous lecture on December 30, 1913, in a joint session of the American Astronomical Society and the American Association for the Advancement of Science at Atlanta, Ga. Following some earlier work by himself and by Hertzsprung, he had plotted the luminosities of the stars against their spectral types. The majority fell in a narrow band, the main sequence, with the rest of the stars forming a broader band running approximately horizontally from left to right — the giant sequence. The spectral types, *B, A, F, G, K, M,* and *N*, are essentially measures of the surface temperatures of the stars, running from about 20,000° at spectral class *B* to about 2,500° at class *N*. Because of the relation between L, T, and R, which we have already discussed and which is written $L = 4\pi R^2 \sigma T^4$, it is always possible to transform the original H-R diagram into another diagram in which the horizontal scale is not the temperature, but the radius. In this representation of the *radius-luminosity relation*, the main characteristics of the H-R diagram are retained, but the sequences are tilted in a slightly different manner. It is most astonishing that the sequences are so clearly marked, both in the L, R projection and in the L, M projection.

During the 36 years since Russell's lecture, a large amount of information has been accumulated concerning the parameters of the stars. We now know that the relations are statistical in nature; actually there are few, if any, parts of the space enclosed by our model which are "prohibited." For example, it was thought in 1913 that all blue and white stars had large luminosities and fell in the upper part of the H-R diagram. Soon afterwards it became apparent that the companion of Sirius, though white in color, has a very small mass. It was the first clearly recognized member of the white-dwarf group. Later we began to notice that the so-called Wolf-Rayet stars, though very blue and hot, are not as luminous as are the normal *O*-type stars with which they are often combined in binary systems. Still more recently it was recognized, especially by Vorontsov-Velyaminov, that the ordinary novae many years after their outbursts are often blue stars of relatively small intrinsic luminosity. This led to the idea that another complete sequence of stars exists in the H-R diagram, running from top to bottom and joining the very luminous *O*-type stars with the white dwarfs. It is not yet certain that this sequence has a real evolutionary significance, as some astronomers believe. But it must be recognized that representative points may be found in many parts of the octant shown in our model which were previously believed to be completely empty.

We must not confuse this result with

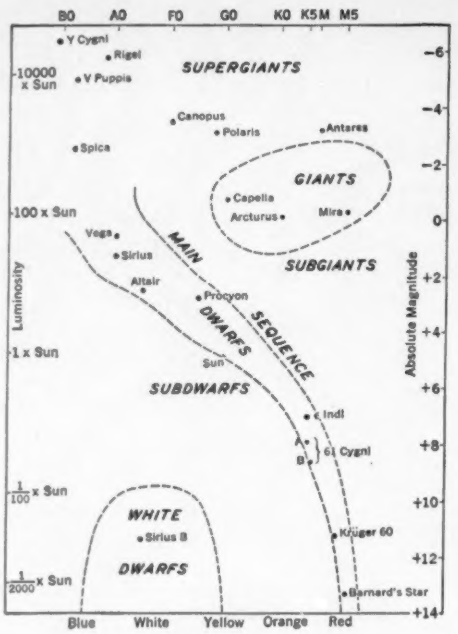


Fig. 3. This H-R diagram shows the positions of many important stars in relation to the main sequence and other statistical groupings. Adapted from "Astronomy," by Skilling and Richardson, published by Henry Holt and Company.

the well-established statistical tendency of the stars of our galaxy to occur in preferential bands within the model. It has been estimated that approximately 100 billion stars of the Milky Way system belong to the main sequence and obey the mass-luminosity relation. The total number of white dwarfs may be 100 times less and the number of subdwarfs may be of the same order. The giants are probably 10,000 times less

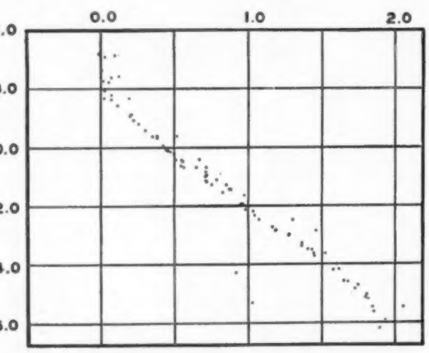


Fig. 4. The Hertzsprung-Russell diagram for the cluster Praesepe according to the work of Heckmann and Haffner in Goettingen. The vertical scale is in magnitudes and corresponds to the scale of Fig. 2, except for an additive constant. The horizontal scale is a measure of the temperature, increasing from left to right. With the exception of the stars at the upper left and a few discordant objects, there is a narrow main sequence whose lower boundary is especially well defined. A few stars which lie above this main sequence are double stars that appear too luminous because the light of the two objects is combined, while the temperature is an average of those of the two stars.

frequent than the main-sequence stars and the supergiants are so rare that there may not be more than 1,000 or 10,000 of them throughout our entire galaxy.

An important quantity is the true spread of the main sequence at right angles to its extent. If we construct a model for a galactic cluster, we obtain an arrangement of the stars that runs almost exactly along a straight line through the octant, with the existing departures almost wholly accounted for by the remaining errors of measurement. This is illustrated by the H-R diagram of the cluster Praesepe in Fig. 4. The exceedingly small spread of the main sequence in the later spectral types of the Hyades has been confirmed by O. J. Eggen. It is accounted for by the fact that the stars in clusters have similar physical properties and were probably formed at the same time. We cannot expect this kind of uniformity when stars selected more or less at random are considered.

For the galaxy in general, the spread of the main sequence at a temperature of about 8,000° K is about two magnitudes. The principal cause of the spread is the chemical composition of the stars. A large amount of hydrogen, compared to other elements, results in a smaller luminosity than would be observed for a star consisting mostly of heavy elements. This relation between the chemical composition and the location of a star within the main sequence led some years ago to the hope that we would be able to determine accurately the abundance of hydrogen in stars and, consequently, their ages. However, more recent work has shown that the problem is not so simple. There are many objects which depart from the main sequence and from the mass-luminosity relation for causes other than those connected with the chemical composition. For example, the companions of certain close double stars, like XZ Sagittarii, R Canis Majoris, and DN Orionis, are fairly luminous objects despite the fact that their masses are only a fraction of the mass of the sun. These stars depart in a most conspicuous manner from the mass-luminosity relation. They are usually subgiants with fairly large radii, exceeding that of the sun by factors of from two to five. But their masses, as we have seen, are often much smaller than the mass of the sun.

It has recently been emphasized, especially by A. J. Deutsch, that instead of using the conventional forms of the L, R and L, M diagrams we should make greater use of some diagrams which were introduced into astronomy years ago by R. Hess. In these, curves were plotted representing lines of equal density referred to a unit of volume in space near the sun. In this manner we would obtain not only the geometrical properties of the different sequences in

(Continued on page 262)

NEWS NOTES

By Dorrit Hoffleit

MIRANDA

From Shakespeare's *Tempest,* Dr. G. P. Kuiper has chosen the name Miranda for the fifth satellite of Uranus. In the June issue of the *Publications* of the Astronomical Society of the Pacific, he gives reason for his choice as follows:

"Uranus' own children, the Titans, are not suitable for mythological reasons; they have been assigned to the son of Uranus, Saturn (Kronos), who gained supreme power after wounding his father. Sir John Herschel named the four bright satellites Ariel, Umbriel, Titania, and Oberon. Oberon and Titania are the king and queen of the fairies in Shakespeare's *Midsummer Night's Dream*; Ariel and Umbriel occur in Pope's *Rape of the Lock,* while Ariel is also found in Shakespeare's *Tempest.* In the *Tempest* Ariel is 'an airy, tricksy spirit, changing shape at will to serve Prospero, his master,' while Miranda is 'a little cherub that did preserve me' (Prospero)."

Miranda was first photographed on February 16, 1948, on a four-minute exposure taken at the Cassegrain focus of the 82-inch telescope at McDonald Observatory (*Sky and Telescope,* April, 1948, page 153). Its nature as a satellite of Uranus was confirmed on March 1st that year, and the orbital motion was later established as roughly circular and in the plane of the other satellites, with a period close to 33 hours, 56 minutes. At present, Daniel Harris is engaged in an exhaustive study of the satellite motions using all previous data on the four satellites as well as the new McDonald material, which consists of about 150 plates.

METEORITICAL SOCIETY

The 12th annual meeting of the Meteoritical Society will be held on Tuesday and Wednesday, September 6-7, at the University of Southern California at Los Angeles. John A. Russell, of the department of astronomy at the university, Los Angeles 7, Calif., is chairman of the program committee.

TELEVISION ON MT. WILSON

A recent note in the Los Angeles *Times* describes the unique setup of seven television broadcasting stations on Mt. Wilson in California. The stations are all in service, on test, or preparing for tests. Five metropolitan daily newspapers, including the *Times* (KTTV) are co-sponsors of as many of the stations, which together serve the southern California coastal plain from Santa Barbara, 100 miles away on the north, to San Diego, 130 miles to the south.

The transmission equipment dwarfs the 100-inch telescope as an investment, for the equipment has cost more than three million dollars. Southern California television fans are fortunate in being able to get all seven stations equally well with a single antenna setting.

YEAR'S SECOND COMET

A 13th-magnitude comet was discovered on a Schmidt camera plate taken at the Oak Ridge station of Harvard College Observatory on the night of July 1-2. The discovery is credited jointly to M. K. Vainu Bappu, Bart J. Bok, and Gordon A. Newkirk, Jr. At this writing there is no indication that the comet will brighten, and on July 4-5, Dr. G. Van Biesbroeck, of Yerkes Observatory, reported it to be of the 14th magnitude. Its position then, July 5.3 UT, was at about $19^h 36^m.1$, $+40^\circ 3'.7$. The discovery position has been determined as at $19^h 47^m.1$, $+38^\circ 35'.8$, on July 2.3 UT.

SPACE TRAVEL

What about space travel? The WAC Corporal 250-mile flight of February 24th, more than doubling the independent high-altitude record of its booster, the V-2, certainly stimulates the imagination and encourages hope for eventual escape from the earth and subsequent travel in interplanetary space. In the May issue of *Scientific American,* the noted rocket expert, Willy Ley, speaks of the WAC Corporal flight as having "opened a window with a view of the nearer areas of our solar system." He comments favorably that a rocket of more than two stages might escape from the earth.

On the other hand, in the May number of *Physics Today,* H. S. Seifert, chief of the applied physics division of the Jet Propulsion Laboratory of California Institute of Technology, and an expert on propellant-cooled motors and heat transfer problems, gives the "somewhat melancholy" opinion that space ships are not around the corner. He writes in an article entitled, "Is the Nuclear-Powered Rocket Feasible?"

Great attention must be paid to reduction of weight for rockets to attain high altitudes. The smaller the payload factor (the ratio of weight of the rocket after its fuel has been spent to the initial launching weight), the better the chances of escape. With known propellants and 50 per cent payload a rocket would go 50 miles; with a 10 per cent payload it would go 500 miles, but such a rocket "has the same ratio of liquid propellant weight to solid skin as has an egg to its shell." This fragility calls for fundamentally stronger construction materials for new rockets.

For a rocket with a 50 per cent payload to go up 500 miles, the energy of the exhaust gases would have to be multiplied by 10. This would imply the availability of a highly concentrated supply of energy, which suggests nuclear energy. But then there is the problem of temperatures. The temperature of the gases in the combustion chamber of a rocket is higher than the melting point of their container. Dr. Seifert asks:

"What are the chances for reaching the thermodynamically necessary temperatures of five thousand degrees Fahrenheit or higher by the use of a nuclear reactor or radioactive pile?" The melting point of uranium metal is somewhat below 3,400° F. Numerous similar questions of feasibility lead the Caltech scientist to conclude that the nuclear rocket seems to be one of the less practical applications of nuclear energy, and it may take decades before a nuclear-powered rocket is successfully launched.

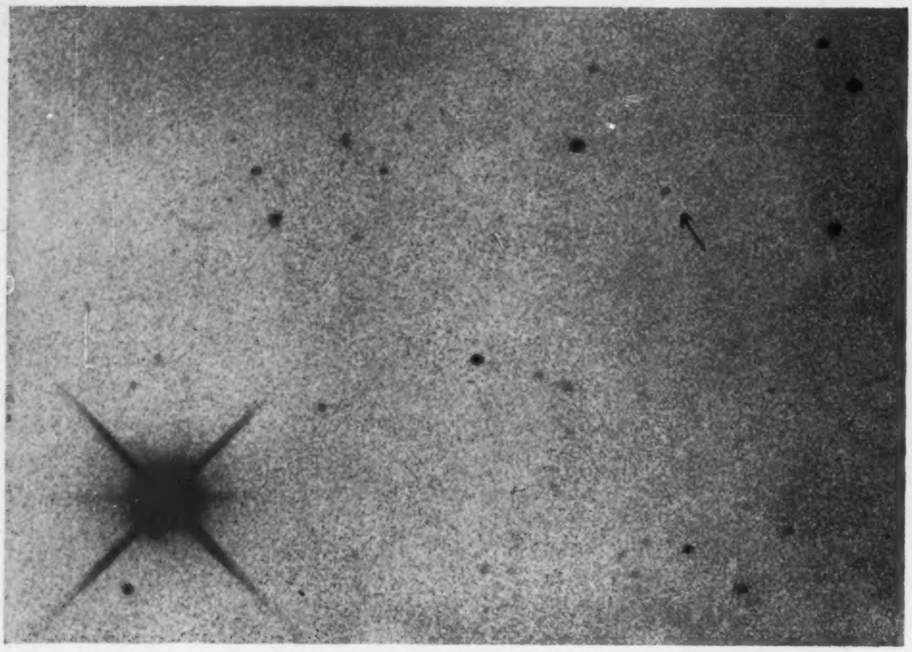
NEW TEMPERATURE SCALE

The first revision of the international temperature scale since its adoption 21 years ago was made at Paris in October, 1948, by the Ninth General Conference on Weights and Measures. Beginning this January, the National Bureau of Standards began using the new definitions. The six fixed points on the temperature scale are the boiling point of oxygen (−182.97° C.), the freezing and boiling points of water, the boiling point of sulphur (+444.60° C.), the melting point of silver (+960.8° C.), and the melting point of gold (+1,063° C.). The Ninth General Conference decided to abandon the designation "centigrade" and to use "Celsius" instead. Anders Celsius, a Swedish astronomer, invented the centigrade scale in 1742.

BEE COMPASS

Sunlight and the polarized light of the sky appear to enable a scout bee which has discovered a source of nectar to orient herself when executing a bee dance to tell other bees about her find. Distance is indicated by the dance pattern, direction by the way the bee's body is pointed most of the time, according to the Austrian entomologist, Professor Karl von Frisch. Science Service reports his announcement of this discovery at a recent meeting of scientists in Washington, D. C.

In total darkness or red light (which bees cannot perceive) the finder-bee became confused in her dance, but oriented herself toward the nectar find when a flashlight was held in the approximate position of the sun. When the flashlight "sun" was held in a false position, the bee gave an incorrect direction. The bee was also properly oriented when she could see a small patch of blue sky (polarized light), but became confused in the unpolarized light of a white cloud drifting across the opening.



Neptune's second satellite, indicated by the arrow, is a considerable distance from the planet (overexposed spiked image). Triton's image blends with Neptune's and is just below it. McDonald Observatory photograph.

AMERICAN

Here are highlights of some paper at Ottawa, Canada, on June 19-2

Neptune Satellite Confirmed

DR. G. P. KUIPER, Yerkes and McDonald Observatories, confirmed his discovery of a second satellite to the planet Neptune, originally reported on Harvard Announcement Card 994 (*Sky and Telescope,* June, 1949, page 193). At present, the preliminary orbit is assumed to be circular, inclined about five degrees to the ecliptic, but the sense of the revolution, direct or retrograde, had not yet been determined.

The angular distance between the new moon and its primary planet is 410 seconds of arc as seen at their average distance from the sun, 30.1 astronomical units. This corresponds to a radius for the new satellite's orbit of five million miles, whereas that of Triton, Neptune's 13th-magnitude satellite, is only about 220,000 miles. The period of the satellite is about two years, and its diameter is about 200 miles, as estimated from its photographic magnitude of 19.5.

In addition to the discovery plates on May 1st, and three more plates on May 29th, photographs of the new satellite were procured at McDonald Observatory during the second half of June. Three or more positions of the satellite thus become available, to make possible complete computation of the orbit.

One Hundred Meteor Spectra

JUST OVER 100 meteor spectra showing recognizable detail have been secured to date, according to a compilation by Dr. Peter M. Millman, Dominion Observatory, who was a speaker at the symposium on meteoric astronomy. Some have been procured by chance, and others on specific programs of meteor photography. Of a total of 104, Dominion Observatory accounts for 37, Harvard Observatory for 19, and David Dunlap Observatory for 13. In the U.S.S.R., eight meteor spectra have been obtained, and the Texas Observers at Ft. Worth have seven. The late Latimer J. Wilson, Nashville, Tenn., obtained six such photographs, while Mount Wilson Observatory and Mount Palomar Observatory are credited with four each, and there are six others.

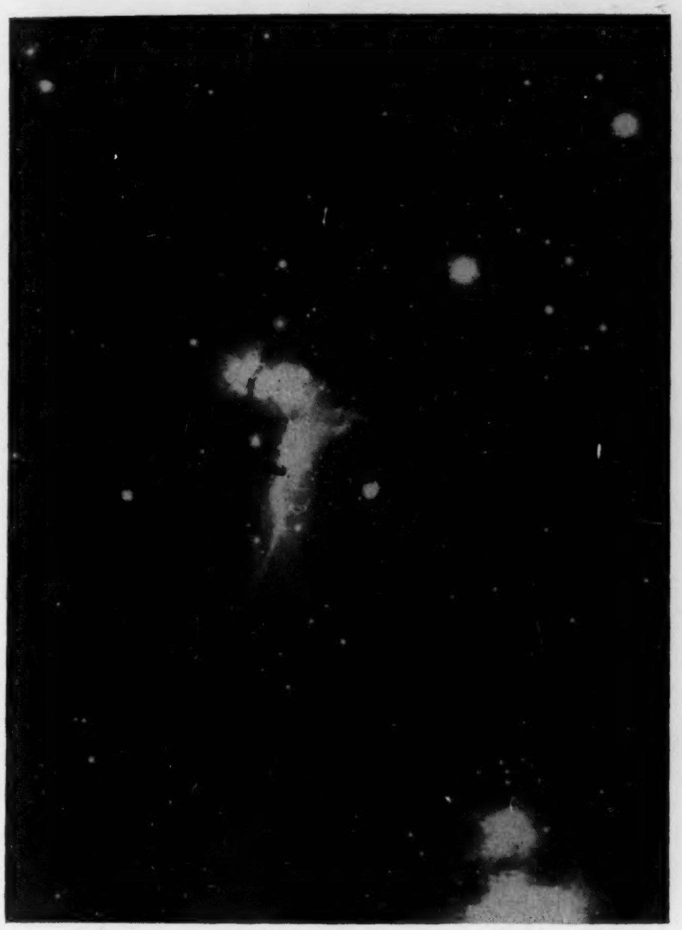
Ten or more spectrum lines are shown in 53 of the spectra; in the most detailed one a total of 64 lines was measured. The visual magnitude estimates, available for 59 spectra, range from $+1\frac{1}{2}$ to -9, with a mean of -2. Dr. Millman points out that these represent objects that have little chance to fall as meteorites. All meteor spectra seem to consist of bright lines or bands, formed chiefly by the low excitation atomic lines of such common elements as iron, sodium, calcium, magnesium, manganese, chromium, silicon, nickel, aluminum, with reasonably good evidence for the FeO molecule in two of the Mount Wilson spectra.

The spectra from a major meteor shower are remarkably similar to each other. The 26 Giacobinids (slow moving) show very low excitation with no ionized elements; some of the 10 Geminids, also slow moving, may show very weak ionized calcium lines. The Perseids, of which there are 25 spectra, show strong lines of ionized calcium,

Members and guests of the American Astronomical Society, at its 81st meeting, June 19-22, 1949,

N ASTRONOMERS REPORT

e papers ...sented at the 81st meeting of the American Astronomical Society
une 19-2... Complete abstracts will appear in the Astronomical Journal.



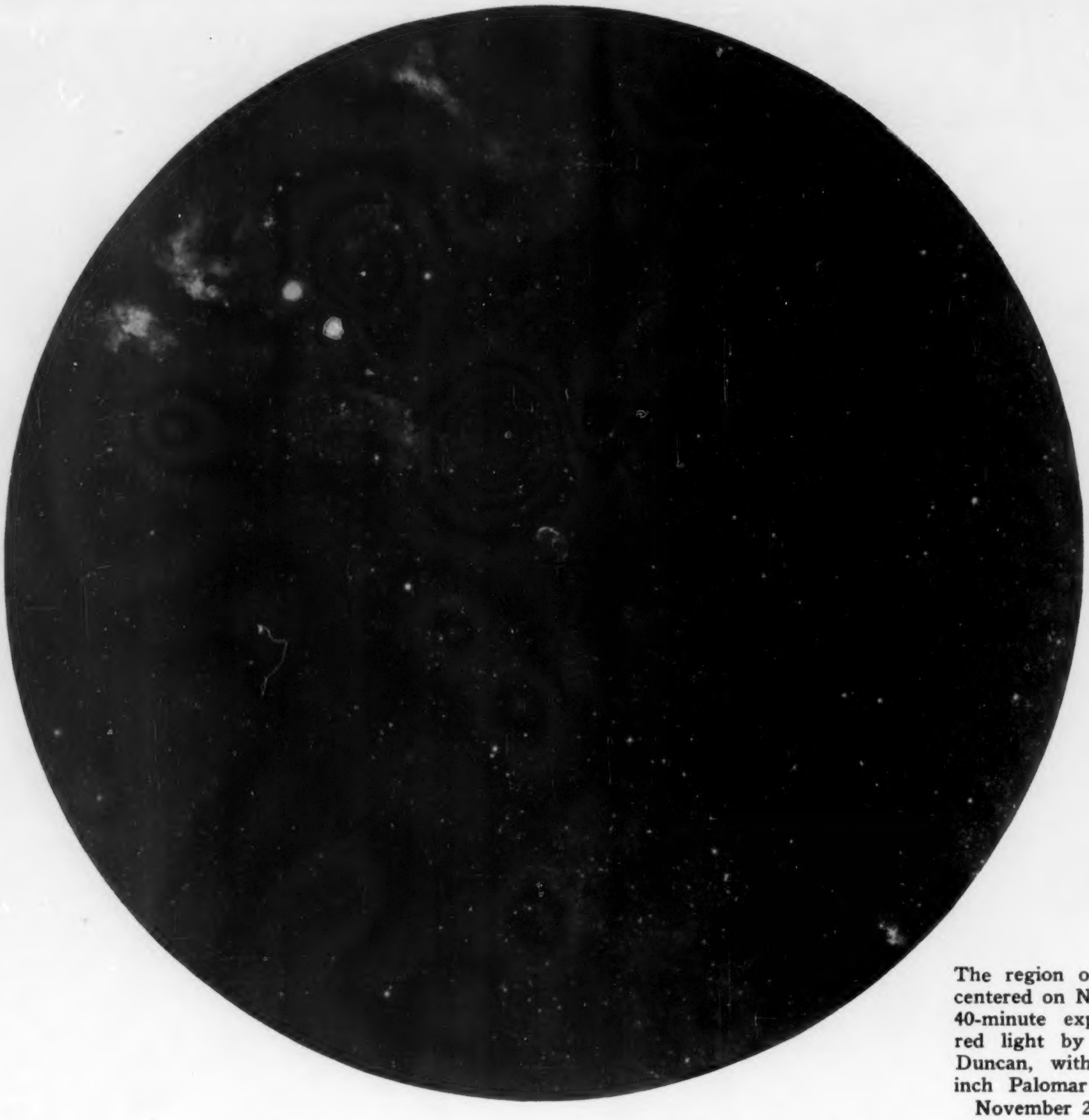
Photographs in red light with the 18-inch Palomar Schmidt camera, by John C. Duncan, on October 3, 1948, show (left) Orion's belt and part of the sword and (above) a region of Sagittarius - Serpens - Scutum.

magnesium, and silicon. These rather fast-moving meteors and the fast Leonids and Orionids have similar spectra. Thus, the excitation seems to depend chiefly on the geocentric velocity of the meteor producing the spectrum. Eleven meteor spectra show color or excitation changes. In all but one case the change is from red to blue and from low to higher excitation.

Galactic Nebulae in Red Light

DIFFUSE NEBULAE in the regions of Orion, Sagittarius, and Cygnus were photographed last year by Dr. John C. Duncan, with the 18-inch Schmidt camera on Palomar Mountain and the 60-inch and 100-inch reflectors on Mount Wilson. He used rapid red-sensitive emulsions (Eastman 103aE) and filters (Plexiglas 160) which confined the light employed to a band about 200 angstroms wide in the hydrogen alpha region of the spectrum. Some of Dr. Duncan's pictures are reproduced here, and one centered on M43 in Orion is on the back cover this month. At the Ottawa meeting, 18 of these photographs were presented as lantern slides, to-

22, 1949, ... front of the National Research Council building, Ottawa, Canada. Photo by Lingard Photographers.



The region of Cygnus centered on NGC 6888; 40-minute exposure in red light by John C. Duncan, with the 18-inch Palomar Schmidt, November 28, 1948.

gether with a few photographs made earlier in blue light.

In Orion, faint nebulosity fills the region south of the belt and including the sword, and exhibits remarkable and beautiful forms. Shown in great detail are the Orion nebulae, M42-43; the region of the dark Horsehead, Barnard 33; and the nebula east of Zeta Orionis, NGC 2024. South of Sigma Orionis is a nearly straight edge, 20 or more light-years long, which divides a brighter and a fainter nebulous field, as shown in the picture on the preceding page. The exposure was 45 minutes, and the reproduction scale is one millimeter to 172 seconds of arc. The famous Great Nebula in Orion is at the border on the south, and the Horsehead dark nebula is near the center.

In Sagittarius, faint extensions appear around M8. Farther north, similar extensions appear around M17, M16, and an uncatalogued nebula in Serpens visible only in red light, as shown just above the center of the right-hand picture on the preceding page. Near the south border is M17, the Omega nebula, and three degrees above it is M16, with notable faint extensions also visible only in red light. The exposure time was 20 minutes, and the reproduction scale is one millimeter to 190 seconds of arc.

More than 100 square degrees of the sky, extending from Eta Cygni on the south beyond Deneb and NGC 7000 to Omega Cygni on the north, are filled with faint nebulosity, the brightest part of which is the nebulous region around Gamma Cygni, discovered by Barnard.

Compare the two photographs above and opposite, of the same region in Cygnus. The picture in panchromatic emulsion (without filter) shows the faint diffuse nebulae near Gamma Cygni, in the northeast quadrant. The head of the great rift in the Milky Way shows dark in the southwest quadrant. North of it is the triangular dark nebula Barnard 145. At the center, barely detectable, is NGC 6888, a nebula which encloses the Wolf-Rayet star BD $+37°$-3821. The photograph in red light, above, greatly enhances the nebulae near Gamma Cygni, and the crescent shape of NGC 6888 is clearly seen. Near the southwest border is a diffuse nebula which in blue light appears as a nebulous star, BD $+34°3828$. The scale of these reproductions is one millimeter to 188 seconds of arc.

A remarkable feature of some nebulae, strongly revealed on red photographs, is a dark core from either side of which extend plumes or brushes of luminous nebulosity. This appearance is shown in the space between M42 and M43 (see back cover), in NGC 2024, in the brightest nebula near Gamma Cygni, and in NGC 6334 Scorpii, a nebula photographed by Dr. Duncan and reported to the American Astronomical Society in 1940.

LEON CAMPBELL HONORED BY HARVARD

In culmination of a career of 50 years devoted to astronomy, the last several decades particularly with the American Association of Variable Star Observers, Harvard University awarded to Leon Campbell at its commencement exercises in June an honorary master of arts degree. The story appeared, among other places, in *Time* magazine for July 4, 1949.

The same region as that opposite, but a 20-minute exposure with panchromatic emulsion, November 28, 1948. The bright star (upper left) is Gamma Cygni.

A NEW ATLAS AND THE FIRST HALE PHOTOGRAPHS

(Continued from page 242)

seeing was never better than "average," the aluminum coat was dusty and grimy, and the mirror showed turned-up edge. These handicaps will be eliminated or avoided in time, but during the tests they caused some loss of light and appreciable loss of definition.

"Nevertheless," writes Dr. Hubble, "the test plates record stars and nebulae fully 1.5 magnitudes fainter than the extreme limit of the 100-inch reflector on Mount Wilson. The faintest star images, on the better plates, were, however, a little more than 1" in diameter, and, at the threshold, it was sometimes difficult to distinguish with certainty between stars and nebulae.

"Thus the 200-inch has registered already the full gain in light-gathering power corresponding to the size of the main mirror. The slight additional gain that may be expected with a clean, sensibly perfect mirror surface will be accounted for by the absence of a Newtonian flat and by the very transparent sky over Palomar.

"The greatest improvement in the future will be in definition, as indicated by the size of faint star images. This attribute is very sensitive to seeing, and, while the test plates approached the definition to be expected under average conditions, they indicated that the mirror is not yet in shape to operate at maximum efficiency on the rare nights of fine seeing. The trouble arises from the turned-up edge and can be eliminated by the retouching now in progress. . . .

"The turned-up edge was well known from Hartmann tests, and its effects could be predicted with some confidence. The photographs were made primarily to confirm and record these effects. However, the first plates were so impressive that a set of full exposures was made to serve as a record of performance before the mirror was removed for retouching. About sixty photographs were assembled over the three months from January 26 to April 28, as opportunities arose during the normal program of adjustments. . . . "

In the **Publications,** the first Hale telescope photograph, recorded as PH-1-H (Palomar, Hale, No. 1, followed by Hubble's initial), made about 10:00 p.m. January 26, 1949, is reproduced. It is a 15-minute exposure of NGC 2261, a well-known variable galactic nebula with the star R Monocerotis at its apex. It was taken after a wait of more than a week for a break in the weather, and the trial was successful except for the large size of the star images produced by poor seeing. Other pictures reproduced with Dr. Hubble's article are of Selected Area 57, where reliable sequences for faint stars are available to the 21st magnitude; Messier 87, a bright member of the Virgo cluster; NGC 5204, a dwarf, late-type spiral in Ursa Major; NGC 3359, about five million light-years distant and for which the brightest stars are resolved by the 200-inch telescope; and globular cluster Messier 3, photographed with a Ross correcting lens and aperture of 160 inches. The Ross lens increases the usable coma-free field at full aperture from 5' to 15' in diameter.

BOOKS AND THE SKY

THE FACE OF THE MOON

Ralph B. Baldwin. University of Chicago Press, Chicago, 1949. 239 pages. $5.00.

IN THIS VOLUME Dr. Baldwin has made a genuine contribution to our understanding of the origin of the lunar surface features. The world's increasing use of high explosives, unfortunate as this may have been, nevertheless provides us with a wealth of information as to the characteristics of explosion craters. This information Baldwin has coupled with an extremely thorough study of the moon's surface features to construct an almost unassailable argument for the explosive origin of the major lunar craters. The meteoric impact theory follows as a natural consequence, although Baldwin is not as thorough in disproving proposed "geological" processes as in demonstrating the explosive process.

I will not attempt to list or repeat all of Baldwin's many cogent arguments; the reader will enjoy meeting them in the text. Two major contributions deserve special mention, however. First is his demonstration that the relation between the diameter and the depth of explosion craters forms a continuous smooth curve beginning with those from mortar shells and ending with the largest lunar craters. Bomb craters, explosion pits, and known meteorite craters fall in between. Terrestrial calderas of collapse are relatively shallow for their widths. Another important contribution is the chapter on "Fossil Terrestrial Meteorite Craters." Here Baldwin amasses the evidence answering the old objection to the meteoritic hypothesis: "If the lunar craters were formed by meteorites, why aren't similar craters observed in geological formations?"

The reader who has previously held to a "volcanic" type of origin for the lunar craters will be strongly irritated by the general tenor of Baldwin's attitude toward "geological" theories of large crater formation. The book might well have followed a less explosive emotional pattern — but the facts and demonstrations would have remained the same. When the "volcanic" reader realizes that Baldwin would even initiate the maria by meteorites, he may also explode. I recommend strongly, however, that he hold his patience while following the arguments carefully in conjunction with a good set of lunar prints.

Personally, I felt a strange sense of awe and bewilderment in trying to visualize 10^x cubic miles of stone being expelled violently from the heart of Mare Imbrium. But in studying the mass of rubble called the Apennine Mountains, and especially the torn, littered, and striated areas to the south of them, I could not avoid being drawn towards Baldwin's point of view. His many supporting arguments combine to make worthy of serious consideration this hypothesis of meteoritic origin for the maria. It is possible to find a number of minor flaws in Baldwin's thesis, but it is more difficult to find major ones. Final proof in such matters is practically impossible until the moon is explored by rocket, a feat perhaps not so very far in the future.

A very beautiful proof that the maria were formed before the moon's tidal bulge was frozen is presented in Chapter 10, "Ancient History." Although the conclusion might be reached from physical

NEW BOOKS RECEIVED

PHILOSOPHY OF MATHEMATICS AND NATURAL SCIENCE, *Hermann Weyl*, 1949, *Princeton University Press.* 311 pages. $5.00.

This is a revised and augmented translation of Professor Weyl's "Philosophie der Mathematik und Naturwissenschaft," published originally in 1927 in Oldenbourg's *Handbuch der Philosophie.* The book discusses man's endeavors to analyze his knowledge of nature.

TERRESTRIAL MAGNETISM AND ELECTRICITY, edited by *J. A. Fleming*, 1949, *Dover Publications.* 794 pages. $4.95.

Originally published in 1939 by McGraw-Hill, this is a reprint of the first edition with corrections made in 1949. Its 14 authors cover in great detail the earth's magnetism and magnetic prospecting, atmospheric electricity and the aurora, the upper atmosphere, and the effects of clouds and showers on the atmosphere.

FROM EUCLID TO EDDINGTON, *Sir Edmund Whittaker*, 1949, *Cambridge University Press.* 212 pages. $4.00.

Adapted from the Tarner lectures of 1947, this book traces the evolution of concepts and principles in physics from the rediscovery of Euclid by western scholars to the present time.

Planetarium Notes

BALTIMORE: *Davis Planetarium.* Maryland Academy of Sciences, Enoch Pratt Library Building, 400 Cathedral St., Baltimore 1, Md., Mulberry 2370.

SCHEDULE: 4 p.m. Monday, Wednesday, and Friday; Thursday evenings, 7:45, 8:30, 9:30 p.m. Admission free. Spitz projector. Director, Paul S. Watson.

BUFFALO: *Buffalo Museum of Science Planetarium.* Humboldt Parkway, Buffalo, N. Y., GR-4100.

SCHEDULE: Sundays, 2:00 to 5:30 p.m. Admission free. Spitz projector. For special lectures address Elsworth Jaeger, director of education.

CHAPEL HILL: *Morehead Planetarium,* University of North Carolina, Chapel Hill, N.C.

SCHEDULE: Daily at 8:30 p.m.; Saturday and Sunday at 3:00 p.m. Zeiss projector. Director, Roy K. Marshall.

CHICAGO: *Adler Planetarium.* 900 E. Achsah Bond Drive, Chicago 5, Ill. Wabash 1428.

SCHEDULE: Mondays through Saturdays, 11 a.m. and 3 p.m.; Sundays, 2:30 and 3:30 p.m. Zeiss projector. Director, Wagner Schlesinger.

LOS ANGELES: *Griffith Observatory and Planetarium.* Griffith Park, P. O. Box 9787, Los Feliz Station, Los Angeles 27, Calif., Olympia 1191.

SCHEDULE: Wednesday and Thursday at 8:30 p.m.; Friday, Saturday, and Sunday at 3 and 8:30 p.m.; extra show on Sunday at 4:15 p.m. Zeiss projector. Director, Dinsmore Alter.

NEW YORK CITY: *Hayden Planetarium.* 81st St. and Central Park West, New York 24, N. Y., Endicott 2-8500.

SCHEDULE: Mondays through Fridays, 2, 3:30, and 8:30 p.m.; Saturdays, 11 a.m., 2, 3, 4, 5, and 8:30 p.m.; Sundays and holidays, 2, 3, 4, 5, and 8:30 p.m.; Wednesdays and Fridays, 11 a.m., for school groups. Zeiss projector. Curator, Gordon A. Atwater.

PHILADELPHIA: *Fels Planetarium.* Franklin Institute, 20th St. at Benjamin Franklin Parkway, Philadelphia 3, Pa., Locust 4-3600.

SCHEDULE: 3 and 8:30 p.m. daily except Mondays; also 2 p.m. on Saturdays, Sundays, and holidays; 11 a.m. Saturdays, Children's Hour (adults admitted). Zeiss projector. Director, I. M. Levitt.

PITTSBURGH: *Buhl Planetarium and Institute of Popular Science.* Federal and West Ohio Sts., Pittsburgh 12, Pa., Fairfax 4300.

SCHEDULE: Mondays through Saturdays, 2:15 and 8:30 p.m.; Sundays and holidays, 2:15, 3:15 and 8:30 p.m. Zeiss projector. Director, Arthur L. Draper.

SPRINGFIELD, MASS.: *Seymour Planetarium.* Museum of Natural History, Springfield 5, Mass.

SCHEDULE: Tuesdays, Thursdays, and Saturdays at 3 p.m.; Tuesday evenings at 8 p.m.; special star stories for children on Saturdays at 2 p.m. (Closed July to mid-September.) Admission free. Korkosz projector. Director, Frank D. Korkosz.

STAMFORD: *Stamford Museum Planetarium.* Courtland Park, Stamford, Conn.

SCHEDULE: Showings by request only, during summer months, until October. Admission free. Spitz projector. Director, Ernest T. Ludhe.

reasoning, Baldwin's demonstration puts the question on ice.

In following the detailed discussions, I found that the reproductions in **The Face of the Moon** were printed on too poor a paper and were of too small a scale in most cases for me to distinguish the critical surface features. For such reference, original prints of the magnificent Mount Wilson and Lick photographs would be most desirable, but the **Sky and Telescope** Moon Sets from Lick Observatory negatives served admirably, especially after my wife reassembled them to form a complete lunar disk, as many amateurs have done. The publishers have marred an otherwise well-printed book with such poor reproductions, whereas good prints could easily have been tipped in as there are only 18 halftone plates all told. Incidentally, the frontispiece and Plates XIII and XVI are inverted from the standard telescopic orientation used for the remaining lunar pictures in the book.

The Face of the Moon represents such a milestone of progress in studies of the origin of lunar features that it is a must for everyone who has an interest in the subject. Although certain small parts of the book may be too difficult for the reader without special training in physics and geology, all of the important arguments can be followed by the average intelligent layman. The book is by no means light reading, but it well justifies considerable effort.

FRED L. WHIPPLE
Harvard College Observatory

GLEANINGS FOR ATM's

The Ball Spherometer

To my knowledge, the ball spherometer was first used several years ago at Howell and Sherburne & Co., of Pasadena, Calif. Don M. Perry, the optical engineer of the plant, devised it in order to do away with the approximations of the standard forms of spherometer. He had several of different sizes made up for use in the shop. None of the opticians had any trouble with the ball spherometer in actual use; in fact, they soon grew to have great confidence in its accuracy and dependability.

In principle, it is like any standard spherometer. In construction it employs three ball bearings instead of the three sharp points that rest against the surface being measured. Balls matched for exactly uniform diameters are mounted against the side of a groove in the base of the instrument as shown in Figs. 1 and 2. A retaining ring screwed into place holds them firmly. A micrometer head or an indicator operates through the center of this base as usual. The balls theoretically can be anywhere in the groove, but obviously spacing of about 120 degrees is most practical, as shown in Fig. 1.

The operation is as with the ordinary spherometer. The instrument is first zeroed by placing it on an optical flat and reading the indicator. It is then placed on the spherical surface, the radius of which is desired, and the indicator read again. The difference in these readings is the **h** used in the standard formula:

$$R = \frac{r^2 + h^2}{2h}$$

When this is solved for **h**, amateur telescope makers will recognize it as the familiar $h = r^2/2R$ formula, but in its exact form. The **R** now involved, however, is not the radius of the spherical surface being measured, but it is the radius of a spherical surface through the center of the balls and concentric with the surface we wish to measure. In order to convert the **R** in the formula above to the radius of the surface being measured simply **subtract for convex** surfaces or **add for concave** surfaces one half the diameter of the balls. The operation of the formulae in both cases is shown in Fig. 3.

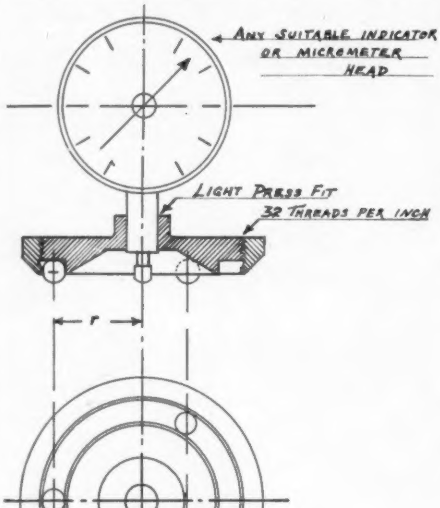


Fig. 1. A suggested design for the ball spherometer. All diagrams with this article are by P. M. Casady.

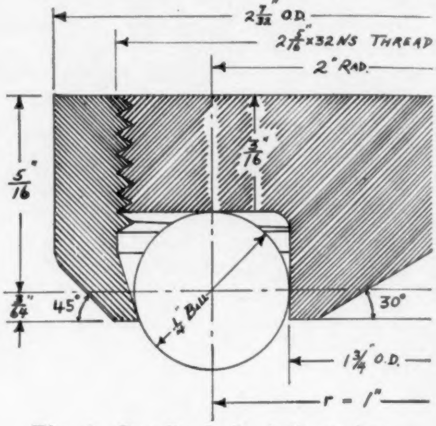
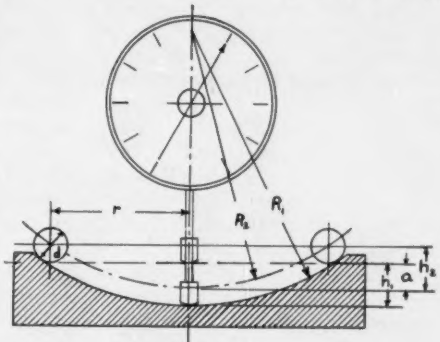


Fig. 2. Detail of the ball retainer.

where the balls are drawn 180° apart as a matter of clarity.

Note that adding and subtracting of the half-diameter of the balls when determining **h** is the reverse of the practice in determining **R**. The formulae and symbols used follow Hardy and Perrin in their **Principles of Optics** rather than the ones used in **Amateur Telescope Making Advanced.** The use of **h** for the sagitta reading instead of **d** allows us to use the latter symbol for the diameter of the balls of the spherometer.

The symbol **r** is the radius of a circle through the center of the balls and in a plane perpendicular to the stem of the indicator. It is, of course, a fixed quantity and may be any value chosen when the spherometer is made, and to as high a degree of precision as desired. Naturally, **r** should be made a convenient integral number, so that its use as the square in the formula will be easy. For instance, for an amateur making a small achromat of three inches diameter, if **r** is made equal to one inch its square will still be one. In this case the balls might well be ¼ inch, which would make the diameter of the cylindrical surface against which they abut about 1¾ inches.



h_1 IS AS MEASURED WITH INDICATOR

$h_2 = h_1 - a + \frac{d}{2}$

USING h_1 IN FORMULA GIVES R_2 TO THE CENTER OF THE BALLS.

FOR CONCAVE SURFACES:-

$$R_1 = R_2 + \frac{d}{2} = \frac{r^2 + h^2}{2h} + \frac{d}{2}$$

$$h = R_2 - \sqrt{R_2^2 - r^2} = \left(R_1 - \frac{d}{2}\right) - \sqrt{\left(R_1 - \frac{d}{2}\right)^2 - r^2}$$

FOR CONVEX SURFACES:-

$$R_1 = R_2 - \frac{d}{2} = \frac{r^2 + h^2}{2h} - \frac{d}{2}$$

$$h = R_2 - \sqrt{R_2^2 - r^2} = \left(R_1 + \frac{d}{2}\right) - \sqrt{\left(R_1 + \frac{d}{2}\right)^2 - r^2}$$

Fig. 3. These formulae are to be used with the ball spherometer.

Since in most optical work the metric system is used instead of the inch system, perhaps it would be better to use balls made for metric-dimensioned bearings, dimensioning the locating groove accordingly and getting a metric micrometer head for the measuring device. A micrometer head is cheaper and probably more accurate and durable than the indicator and therefore more desirable for the amateur, but for some classes of work where ease and speed of reading are required the indicator is probably better.

In case a micrometer head is used, it should have the end of the spindle ground to a curved surface or a blunt conical point so that each concave surface can be properly contacted at its lowest point. The head from a thread comparator micrometer, which has the end of the spindle already pointed, could be used, or a ball attachment may be purchased and slipped over the normally flat spindle end. The size of the ball in the attachment has no effect on the readings and may be either of inch or metric dimensions. Any micrometer manufacturer can supply a ball of this type as it is standard equipment for measuring against curved surfaces.

This spherometer is very rugged and durable. It is in very little danger of

damage or loss of accuracy in ordinary use. The balls are of fine alloy steel, but if they are suspected of wear at the points of contact with measured surfaces or of slightly sinking into the grooved ring against which they rest, the retaining ring can be easily and quickly loosened and the balls turned and moved to new positions, making the instrument again as good as new. Or new balls can be easily and cheaply put in place. In cases where extreme accuracy and durability are desired, the base can be made of hardened tool steel and the groove face against which the balls lie can be ground to as exact a diameter as one can measure, using "Jo" blocks if desired. For the amateur, however, plain turning from brass with careful use of the micrometer caliper should give all the accuracy necessary. Altogether this ball spherometer is a very practical and satisfactory instrument.

It is interesting to note from the formulae in Fig. 3 that if one is using a standard three-point or a ring spherometer and the radius of the points or the radius of the edge of the ring is known, such radius can be considered as the half diameter of balls and applied to the formulae similarly for more accurate results. The trouble here, however, might be that the different points probably would have different radii, or that they might have gotten bent out of their original circle, or that the ring edge might have become nicked or otherwise deformed.

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THE TWO FUNDAMENTAL RELATIONS OF STELLAR ASTRONOMY

(Continued from page 252)

each of the two projections of our model, but we could read off directly the probability of finding a star at a given point. Without a clear recognition of the stellar densities in space, we shall not have an adequate basis for studying the origin and the evolution of the stars. For example, it must be cosmogonically important that along the main sequence the density increases from top to bottom, so that the red dwarfs are 100 or 1,000 times more frequent, per unit volume, than are the blue stars.

The model of Fig. 1 applies only to our galaxy and to what W. Baade has called the "local swimming hole," that is, the region of space immediately surrounding the solar system. In the central regions of our galaxy, and in extragalactic systems, the distribution of the stars in our model would be entirely different. This has led to the recognition of different types of populations in the universe. Long ago H. Shapley noticed that in globular clusters the giant sequence is quite different from that of our galaxy, and Baade has introduced the term *Population II* to describe the arrangement of the stars with respect to L, M, and R, in globular clusters and in the central nucleus of our galaxy.

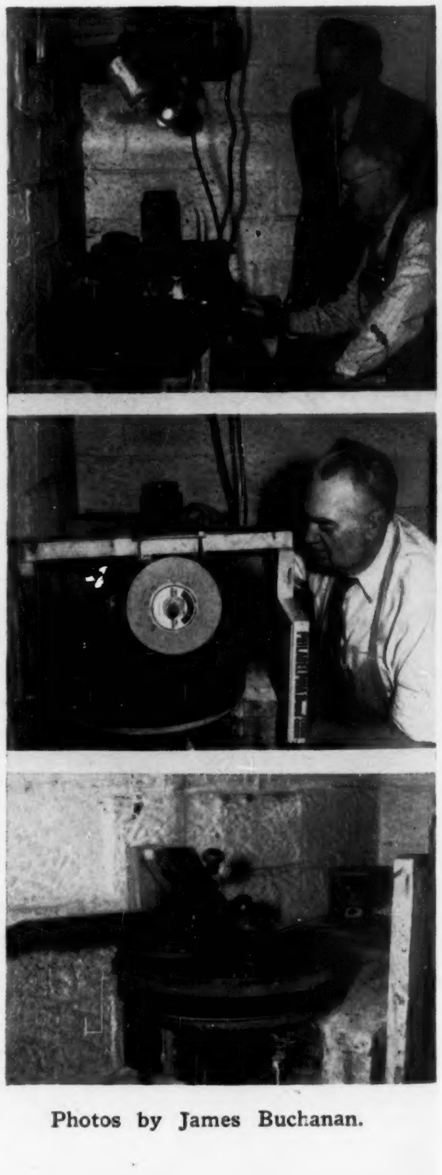
YOUNGSTOWN ASTRONOMY CLUB WORKS ON 16-INCH REFLECTOR

The Youngstown Astronomy Club has undertaken the building of a 16-inch Cassegrainian telescope, complete with mounting and shelter. This is a large project, and when completed the instrument should show stars to the 15th magnitude. The primary focal length is 80 inches and the amplification is 3, making the equivalent focal length 240 inches. The conventional German type of mounting with clock drive and circles will be used.

The club is very fortunate in having the services of one of its members, T. G. Beede, to figure the mirrors. He is a veteran with 51 years of experience at this work. Several of the other members are experienced telescope makers, with many instruments and mountings to their credit.

In the first picture shown here, Edgar A. Miller and Albert P. Gifford (standing) are engaged in edging the 16-inch mirror. The second picture shows the undersigned roughing out the curve with a grinding wheel, after which the mirror was surfaced with a cast-iron lap, as shown in the lowest picture.

LEO F. GRANDMONTAGNE
199 Wychwood Drive
Youngstown, Ohio



Photos by James Buchanan.

OBSERVER'S PAGE

Universal time is used unless otherwise noted.

AN APPARENT TEMPORARY CHANGE IN SATURN'S COLOR

WHIPPLE remarks, "From year to year the shadings of color over Saturn's disc are observed to vary greatly." To judge from isolated references such changes may be profound. Thus Webb cites Browning as giving a "light cinnamon" color to the shaded zones on either side of the white equatorial zone, and himself calls these zones "brown" or "somewhat ruddy." Young stated that the bright equatorial zone "is often of a delicate pinkish tinge." At the opposition of 1916 the entire globe was reported to be a pinkish brown. There can be little doubt that such variations in general color must occasionally affect the naked-eye color of the planet.

On May 13, 1949, observing from 8:10 to 8:22 p.m. EST, the writer found the ball so decidedly reddish that at first he thought he was observing through a thick haze. The appearance of Titan, Iapetus, and Rhea, however (the last two seldom seen above the city lights), presently convinced him that such could not be the case. Accordingly — and somewhat belatedly — a check on transparency was made and the following facts were determined:

To the naked eye, Saturn appeared sensibly ruddy and not at all of its usual golden-yellow tint. Regulus, well placed nearby for comparison, showed no tinge of color and appeared normally white. Moreover, with 2.5x glasses, the 8th-magnitude star near Regulus was clearly visible — which would not have been the case had haze actually been present.

A rather striking confirmation was also obtained from certain searchlights playing over the sky. These were faint and transparent and at their farther ends faded off imperceptibly into the darkness of the sky. On nights of even slight haze the same beams are observed to be brighter, more "solid," and they terminate in diffuse spots of light.

Telescopically, the planet presented an abnormal appearance. The equatorial zone was normally white, but the south tropical zone was abnormally dark and decidedly ruddy. The whole southern hemisphere was so much darker than usual that the shaded south polar zone appeared to blend imperceptibly with the background. The south equatorial belt showed so little contrast with this dark, ruddy background as to be only faintly visible. The south temperate belt was not seen at all. The northern hemisphere appeared to be even darker, and also ruddy, and no belts at all were seen there. The power used was 100x on 3.5 inches of aperture.

At 10:21 p.m. a check observation was made. Though Regulus was not perceptibly affected as to color by the decline in altitude, and in the telescope showed normally white, Saturn looked almost as red as a **K** star. Telescopically the planet presented a somewhat changed appearance. The south polar shading appeared to be lighter, and the south tropical zone was certainly lighter, though deeply ruddy as to color — a sort of pinkish orange. The equatorial zone was unchanged and normally white. The northern hemisphere appeared as before.

Comparisons were made between the telescopic appearance with a Wratten A filter, series 5, deep red, and a Wratten XI filter, series VI, deep green. The ball was perceptibly brighter to the red filter than to the green, though the reverse was noted for the rings. Power and aperture were as before.

The writer has occasionally seen something of the sort before, though not in recent years. On September 21, 1942, at 11:56 p.m. EST, with 150x on a 5-inch refractor, and on a superb night, the whole southern hemisphere was found to be a pale orange hue, which was sufficient to affect the color to the naked eye. Comparison with Aldebaran confirmed a marked similarity of hue.

The writer believes that the observed reddening of Saturn represents a real, though temporary, change in the general color of the planet. Similar experiences in the past suggest that such color changes are rarely of more than a day's duration.

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DEEP-SKY WONDERS

SKIES around the north ecliptic pole, located in Draco at 18^h, $+66\frac{1}{2}°$, are rather barren, but a few interesting objects wait for the zealous observer.

NGC 6543, 37^4, $17^h\ 58^m.6$, $+66°\ 38'$, close to the ecliptic pole, is a bright planetary nebula remembered because it is the first of its type which Huggins found to have a gaseous spectrum, thus forever distinguishing these objects from unresolved clusters or extragalactic nebulae. This occurred August 29, 1864. Herschel gave its diameter as 35″, but Lick **Publications XIII**, 3, says it is 22″ x 16″. The Reverend Webb, with a 3-inch telescope, could only make it 15″. Smyth remarks on its fine pale blue color, but the celestial admiral seems to have had an unusually acute sensitivity for color; most amateurs today can not distinguish the multitude of shades he could. The Lick photograph shows this planetary as a helix with two turns not unlike the famous NGC 7293. Its overall magnitude is 8.5, and its central star is about 9.5. It is located at the northern end of a line of three faint stars (9th magnitude or lower), the stars occupying a length of about $\frac{1}{4}°$.

NGC 6503, $17^h\ 49^m.9$, $+70°\ 10'$, is an Sc-type spiral of magnitude 11.4, 5′ x 1′.

Not shown in Webb's **Atlas** is **NGC**

UNIVERSAL TIME (UT)

TIMES used on the Observer's Page are Greenwich civil or Universal time, unless otherwise noted. This is 24-hour time, from midnight to midnight; times greater than 12:00 are p.m. Subtract the following hours to convert to standard times in the United States: EST, 5; CST, 6; MST, 7; PST, 8. If necessary, add 24 hours to the UT before subtracting, and the result is your standard time on the day preceding the Greenwich date shown. Daylight time is one hour in advance of standard time.

6412, 41[6], 17h 30m.8, +75° 45′. This would appear from the Herschel class to be a rich compressed cluster, yet the Shapley-Ames catalogue classes it as a faint external galaxy of magnitude 12.8, 2′ x 2′, spiral. The NGC description is globular cluster, considerably large (3′ to 4′ in diameter), round, very gradually brighter toward the middle, partially resolved, some stars seen. It may be that foreground stars confuse the picture, and we would appreciate reports from any amateur who has observed NGC 6412 after reading this column.

WALTER SCOTT HOUSTON

MOON PHASES AND DISTANCE

First quarter	August 1, 12:57
Full moon	August 8, 19:33
Last quarter	August 16, 22:59
New moon	August 24, 3:59
First quarter	August 30, 19:16
Full moon	September 7, 9:59

	August	Distance	Diameter
Apogee	13d 20h	251,600 miles	29′ 31″
Perigee	25d 21h	224,500 miles	33′ 04″

MINIMA OF ALGOL

August 2, 20:53; 5, 17:42; 8, 14:30; 11, 11:19; 14, 8:07; 17, 4:56; 20, 1:44; 22, 22:33; 25, 19:22; 28, 16:10; 31, 12:59. September 3, 9:47; 6, 6:36; 9, 3:24.

JUPITER'S SATELLITES

On August 4-5, all four of the bright moons of Jupiter will be on the east side of the planet, **I, III, II,** and **IV**, in that order outward, at 4:15 UT.

At the same time on August 18-19, the satellites will be on the east side again, and bunched together in a fairly compact group. Satellite **IV** will be south of the equatorial belt, with **II** below it (telescopically), and **III** farther out; **I** will be nearest the planet.

August 25-26 should bring a fine evening of configurations, with all four satellites on the east side again after 0:11.5 UT, when **I** comes out of eclipse in Jupiter's shadow. The order will be then **I, IV, II, III,** with **II** possibly nearer the planet than **IV** early in the evening. As **III** is moving toward Jupiter, the configuration should tighten as the evening progresses.

On August 28-29, until the occultation of **II** which begins at 5:51, the order inward on the west side of the planet will be **IV, III, I,** and **II.**

On September 8-9, after 4:01, all the moons will be on the east side of Jupiter, in numerical order from the planet outward. Note that there is an eclipse reappearance of **II** just at the September configuration time in the table, 2:30, but that **I** does not come out of eclipse until 4:01.

August 1, 3402; 2:56 I Oc, 5:30 I EcR. **2,** 1042; 2:21 I TrE, 2:40 I ShE, 3:21 IV EcR, 3:32 III Oc, 8:26 III EcR. **3,** 20134. **4,** 12034; 9:43 II Oc. **5,** 01324. **6,** 13024; 4:40 II Tr, 5:30 II Sh, 7:28 II TrE, 8:18 II ShE, 10:14 I Oc. **7,** 32014; 7:22 I Tr, 7:49 I Sh, 9:39 I TrE, 10:06 I ShE. **8,** 31024; 2:38 II EcR, 4:40 I Oc, 7:24 I EcR. **9,** 31024; 1:48 I Tr, 2:18 I Sh, 4:06 I TrE, 4:35 I ShE, 6:52 III Oc. **10,** 2013; 1:53 I EcR, 2:44 IV Tr, 6:54 IV TrE, 7:37 IV Sh, 11:51 IV ShE.

August 11, 42103; 12:00 II Oc. **12,** 40123. **13,** 41302; 2:20 III ShE, 6:56 II Tr, 8:05 II Sh, 9:43 II TrE, 10:53 II ShE, 11:59 I Oc. **14,** 43201; 9:07 I Tr, 9:44 I Sh, 11:25 I TrE, 12:01 I ShE. **15,** 4310; 1:10 II Oc, 5:16 II EcR, 6:25 I Oc, 9:19 I EcR. **16,** 4302; 3:34 I Tr, 4:13 I Sh, 5:51 I TrE, 6:30 I ShE, 10:14 III Oc. **17,** 42013; 0:52 I Oc, 3:48 I EcR. **18,** 21403; 0:59 I ShE, 10:49 IV Oc. **19,** 01423. **20,** 13024; 2:47 III Sh, 3:24 III TrE, 6:21 III ShE, 9:14 II Tr, 10:41 II Sh.

August 21, 32014; 10:54 I Tr. **22,** 3104; 3:29 II Oc, 7:54 II EcR, 8:11 I Oc. **23,** 30124; 5:21 I Tr, 6:08 I Sh, 7:38 I TrE, 8:25 I ShE. **24,** 2034; 1:10 II TrE, 2:38 I Oc, 2:45 II ShE, 5:43 I EcR. **25,** 21034; 0:37 I Sh, 2:04 I TrE, 2:54 I ShE. **26,** 01423. **27,** 1402; 1:46 IV Sh, 3:19 III Tr, 6:03 IV ShE, 6:47 III Sh, 6:50 III TrE, 10:21 III ShE. **28,** 43201. **29,** 43120; 5:51 II Oc, 9:58 I Oc, 10:32 II EcR. **30,** 43012; 7:08 I Tr, 8:03 I Sh, 9:25 I TrE, 10:21 I ShE. **31,** 42103; 0:29 III EcR, 0:44 II Tr, 2:33 II Sh, 3:30 II TrE, 4:25 I Oc, 5:20 II ShE, 7:38 I EcR.

September 1, 4203; 1:35 I Tr, 2:32 I Sh, 3:52 I TrE, 4:49 I ShE. **2,** 40123; 2:06 I EcR. **3,** 41032; 6:49 III Tr. **4,** 3201; 2:06 IV Oc, 6:14 IV OcR. **5,** 31204; 8:14 II Oc. **6,** 30124; 8:57 I Tr, 9:59 I Sh. **7,** 1024; 0:53 III Ec, 3:06 II Tr, 4:29 III EcR, 5:09 II Sh, 5:52 II TrE, 6:13 I Oc, 7:56 II ShE, 9:32 I EcR. **8,** 20134; 3:24 I Tr, 4:28 I Sh, 5:41 I TrE, 6:45 I ShE. **9,** 0234; 0:40 I Oc, 2:30 II EcR, 4:01 I EcR. **10,** 10324; 0:09 I TrE, 1:14 I ShE.

In the accompanying data, taken from the American Ephemeris and Nautical Almanac, following each date (in bold-face type) are given the telescopic satellite positions west (left) or east (right) of Jupiter (which is designated 0) at 4:15 UT in August, and at 2:30 in September.

Then are given the Universal time, the satellite (Roman number), and the phenomenon. Tr and TrE are the beginning and ending, respectively, of a satellite transit; Sh and ShE, same for the shadow; Ec and EcR are eclipse disappearance and reappearance, respectively; Oc and OcR, same for occultation.

OCCULTATION PREDICTIONS

Venus will be occulted on the morning of August 26th, for stations in the northeastern states and Canada, but under unfavorable conditions. Immersion occurs below the horizon or just about moonrise. Emersion on the sunward side of the thin 2½-day-old crescent moon will take place about one hour after moonrise at Washington, and correspondingly close to this time at other stations listed. Venus will be of magnitude −3.4, angular diameter only 13″, 81 per cent illuminated.

Optical aid will be required, of course, to observe this emersion in the brilliant morning sky two hours of right ascension east of the sun. Once the moon and Venus are located, the moon may be used as a guide during the day to follow the planet across the sky.

On August 30th, early in the afternoon for stations in the Middle West and Far West, there will be an occultation of Antares; for station **H** immersion will occur below the horizon.

August 6-7 **A Sagittarii** 5.0, 19:55.8 −26-20.1, 12, Im: **A** 6:48.9 +0.2 +1.0 18; **C** 6:45.7 −0.1 −1.1 19. Em. **A** 7:33.9 −1.5 −2.3 296; **C** 7:34.6 −1.7 −2.1 293.

August 25-26 **VENUS** −3.4, 12:27.5 −2-21.4, 2, Em: **A** 14:04.3 −0.4 +1.0 282; **B** 14:06.4 −0.3 +0.7 293; **C** 13:57.9 −0.3 +1.6 265; **D** 14:03.2 −0.2 +1.0 284.

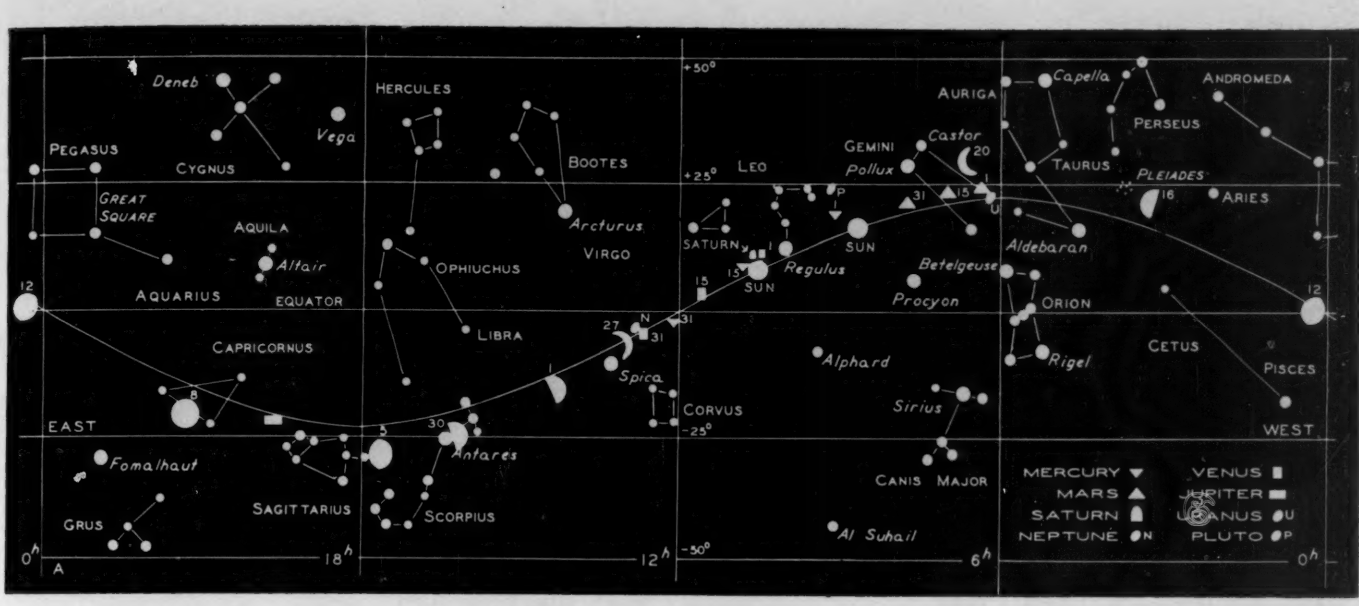
August 30 **Alpha Scorpii** 1.2, 16:26.3 −26-19.2, 7, Im: **E** 21:27.6 −3.2 +3.1 50; **F** 20:59.3 −1.2 +0.8 96. Em: **E** 22:00.3 +0.7 −2.3 354; **F** 22:08.0 −0.9 −0.5 315; **H** 21:51.1 −0.6 +0.6 288.

For standard stations in the United States and Canada, for stars of magnitude 5.0 or brighter, all data from the American Ephemeris and the British Nautical Almanac are given here, as follows: evening-morning date, star name, magnitude, right ascension in hours and minutes, declination in degrees and minutes, moon's age in days, immersion or emersion; standard station designation, UT, a and b quantities in minutes, position angle on the moon's limb; the same data for each standard station westward.

Longitudes and latitudes of standard stations are:

A +72°.5, +42°.5	**E** +91°.0, +40°.0
B +73°.6, +45°.6	**F** +98°.0, +30°.0
C +77°.1, +38°.9	**G** +114°.0, +50°.9
D +79°.4, +43°.7	**H** +120°.0, +36°.0
I +123°.1, +49°.5	

The a and b quantities tabulated in each case are variations of standard-station predicted times per degree of longitude and of latitude, respectively, enabling computations of fairly accurate times for one's local station (long. Lo, lat. L) within 200 or 300 miles of a standard station (long. LoS, lat. LS). Multiply a by the difference in longitude (Lo — LoS), and multiply b by the difference in latitude (L — LS), with due regard to arithmetic signs, and add both results to (or subtract from, as the case may be) the standard-station predicted time to obtain time at the local station. Then convert the Universal time to your standard time.



THE SUN, MOON, AND PLANETS THIS MONTH

The sun, on the ecliptic, is shown for the beginning and end of the month. The moon's symbols give its phase roughly, with the date marked alongside. Each planet is located for the middle of the month and for other dates shown.

Mercury, poorly placed for observation, is in the evening sky all month. After August 11th, the planet sets three quarters of an hour after the sun. Its conjunction with Saturn on the 13th will be visible with slight optical aid.

Venus increases its distance from the sun to about 30° in longitude, but the planet sets less than 1½ hours after sunset. A close conjunction with the moon takes place on August 26th, appearing as a daylight occultation from the eastern United States (see Occultation Predictions). On August 17th, Venus passes ½° north of Beta Virginis; telescopically the planet is gibbous, 84 per cent illuminated.

Mars rises about three hours before the sun and remains a 2nd-magnitude object. During the month it traverses Gemini, appearing south of Pollux by the end of the month.

Jupiter dominates the night sky, as it passed opposition in July. Its motion, in western Sagittarius, is retrograde. The telescopic disk is 47" in diameter. Its satellite phenomena are discussed elsewhere in this department.

Saturn may be found the first week in August very low in the west after sunset. Mercury passes 38' south of it on the 13th.

Uranus rises several hours before the sun; it is moving eastward a little over a degree north of Eta and Mu Geminorum. On the 4-5th, Uranus passes 7½' south of 9 Geminorum, the planet slightly brighter than the star. A remarkably close conjunction with 10 Geminorum (mag. +7.0) takes place on August 14th at 9^h. Uranus is 2.1" south of the star; considering that the planetary disk is 3½" in diameter, this is extremely close.

Neptune is too near the sun for favorable observation.

E. O.

VARIABLE STAR MAXIMA

August 1, RR Scorpii, 6.0, 1650**30**a; 2, S Coronae Borealis, 7.5, 151731; 8, S Ursae Majoris, 7.9, 123961; 10, X Ophiuchi, 6.9, 183308; 15, R Sagittarii, 7.2, 191**019**; 16, S Carinae, 5.7, 1006**61**; 21, S Pavonis, 7.3, 1946**59**; 21, RS Cygni, 7.4, 200938; 23, Omicron Ceti, 3.7, 021**403**; 25, R Virginis, 6.9, 123307. September 2, Chi Cygni, 5.3, 194632; 8, RS Scorpii, 6.8, 164**844**.

These predictions of variable star maxima are made by Leon Campbell, recorder of the AAVSO, Harvard College Observatory, Cambridge 38, Mass. Serious-minded observers interested in making regular telescopic observations of variable stars may write to Mr. Campbell for further information.

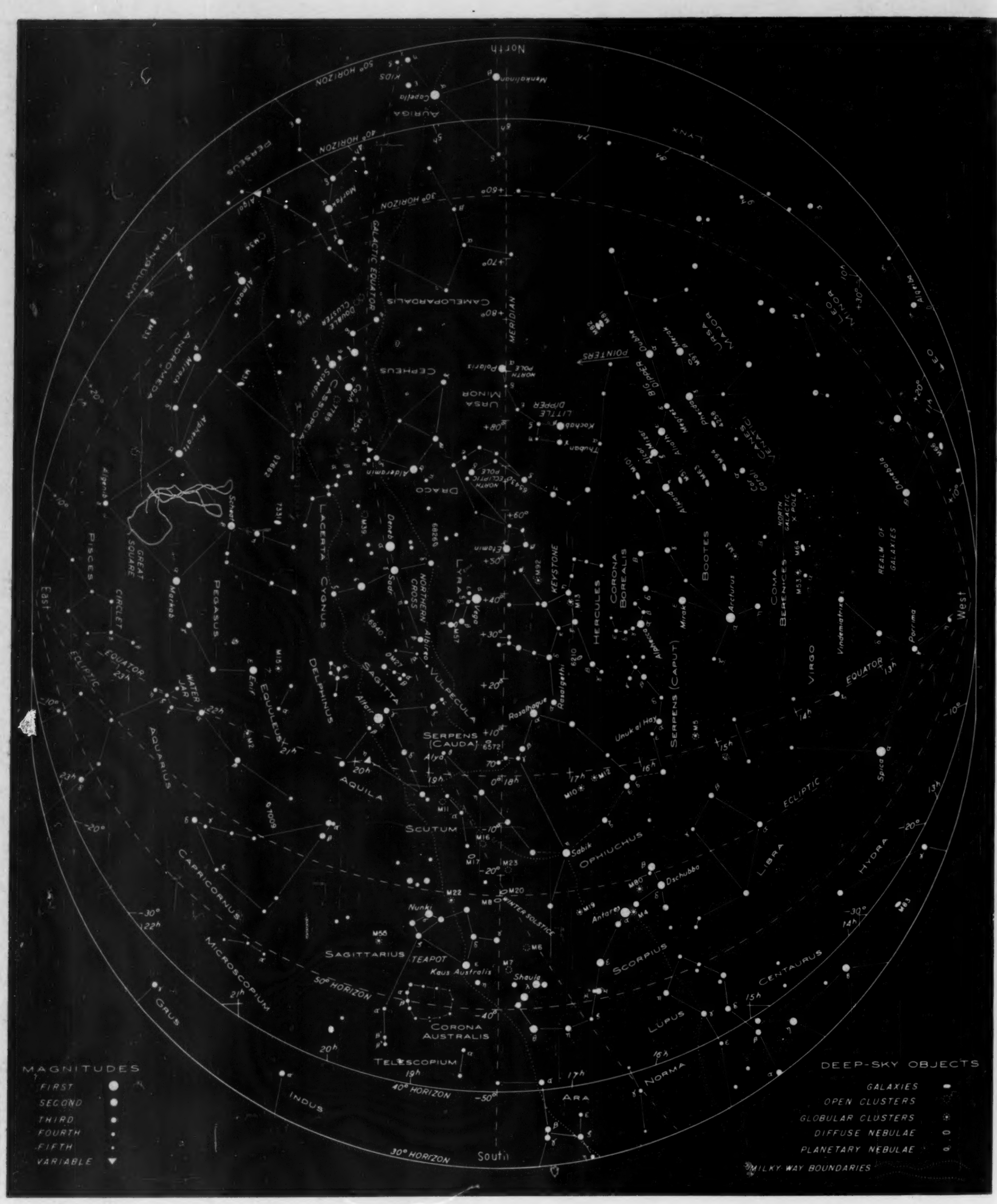
Only stars are included here whose mean maximum magnitudes, as recently deduced from a discussion of nearly 400 long-period variables, are brighter than magnitude 8.0. Some of these stars, but not all of them, are nearly as bright as maximum two or three weeks before and after the dates for maximum. The data given include, in order, the day of the month near which the maximum should occur, the star name, the predicted magnitude, and the star designation number, which gives the rough right ascension (first four figures) and declination (bold face if southern).

METEORS BY MOONLIGHT

The full moon occurs on August 8th, interfering seriously with observation of the Perseid meteors. On clear moonless nights, 60 to 70 meteors per hour may be counted. This year the rate may be 30 an hour after midnight. But the first four nights of August find the moon setting before 1 a.m. local time, and up to 20 meteors per hour may be recorded in this period. From August 8th to 13th, the moon moves through Capricornus, Aquarius, and Pisces, about 90° from the Perseid radiant near Eta Persei.

The Perseid maximum is August 10th to 12th, and the meteors are typically swift. From the writer's observations in the past, a third of all meteors seen will leave trains, and a fair number of Perseids will equal or exceed Jupiter in brightness. At maximum, 85 per cent of all meteors seen will be Perseids. The entire month of August has the highest rate of visual meteors during the year, the average for every night of the month being 19 per hour.

E. O.



The sky as seen from latitudes 30° to 50° north, at 9 p.m. and 8 p.m., local time, on the 7th and 23rd of August, respectively.

STARS FOR AUGUST

HERCULES and Ophiuchus, two mighty figures of ancient mythology, are represented high in the sky this month. As befits the stature of their namesakes, these constellations are large and worthy of study. Hercules is noted for its Keystone, although some prefer to include the stars Beta and Delta to form a butterfly. Rasalgethi, in Hercules' head, is a beautiful orange double star, but it is not conspicuous in the sky compared to Rasalhague, which marks the head of the Serpent Holder.

Just as Hercules stands on Draco in the north, so Ophiuchus stands on Scorpius in the south. Learn the two parts of Serpens when you study Ophiuchus; the X that marks the head of the Serpent is just under the Northern Crown; the tail of the Serpent is immersed in the Milky Way near the brilliant starcloud of Scutum.

Correction: The statement on page 210 in the June issue that Capella is circumpolar for those living midway between the poles should have read "for those living midway between the north pole and the equator." Talmadge Mentall, of Detroit, Mich., has pointed out this error.

The sky as seen from latitudes 20° to 40° south, at 9 p.m. and 8 p.m., local time, on the 7th and 23rd of November, respectively.

SOUTHERN STARS

HIGH in the southeastern sky at this time of year are the Milky Way's two companion galaxies, the Large and Small Magellanic Clouds. Visible to the naked eye as hazy patches of light, long thought to be detached parts of the Milky Way, the clouds took their name from the famous explorer on whose first circumnavigation of the globe they were seen and described by the historian Pigafetta.

In more recent years, such astronomers as Harlow Shapley have turned to the Magellanic Clouds as "astronomical toolhouses" of tremendous value. They are comparatively near to our own galaxy, each less than 100,000 light-years away. They have furnished the information that led to the discovery of the period-luminosity law of Cepheid variation; they are being used in the study of open and globular clusters, of the internal motions in irregular galaxies, and of stellar populations. The Clouds of Magellan are the nearest galaxies that we can study from the outside.

Also near the meridian at this time, but far to the north, is our nearest spiral galaxy neighbor, the Great Nebula in Andromeda, Messier 31. It is roughly 10 times as far away as are the Magellanic Clouds.